Creation of Detonation Chamber for Experimental Determination of Thermodynamic Characteristics of Modern Explosives

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Abstract. The subject of investigation represents the designing data of explosion chamber and calorimetric device. The latter will allow the determination of the parameters of the detonation and energetic characteristics of low-sensitivity, emulsion and outdated explosives. Research methodology provides the study of standard explosives of published data only, which, at experimental investigations in the above-mentioned cases, do not agree with the reality. The question problematical character is lied in the fact that the reduction of explosives sensitivity causes the increase of critical and limiting diameters of tested charge which, for its part, is associated with the increase of charge mass. Above-mentioned increases significantly the limiting values of designed dynamic loads, acting on the walls of explosion chamber and presents a serious hazard to the construction integrity. For problem, solving the new experimental explosion chamber together with calorimetric device was designed. In the chamber, for reduction of quasistatic pressures channels were designed the total area of their surfaces were calculated by theoretical methods together with other designed data of explosion chamber and calorimetric device. The procedure of the devise manufacturing is proceeding.

1. Introduction

Physical essence of chemical transformation of the substance involves the rapid energy release. In this case the transfer of potential energy to kinetic one is characterized by formation of shock wave by reaction products. The major condition for sustainable development of mentioned process is a stable ability of chemical self – transformation of the substance. The rate of chemical self-transformation is determined by detonation and energetic characteristics of the explosives [1-4].

Nowadays in the industry mainly are used simplest type of the explosives which, in general, represent two-component systems and contain fuel and oxidizing elements. Accordance technical and safety regulations, before the use of industrial explosives, (as well as in the case of preparation of their new type of explosives), they must be tested and established the following technological characteristics: Speed of detonation; Sensitivity; Stability; Brisance; Density; Toxicity; Explosion heat/energy and etc. The workability is one of the main technological characteristics of the explosives for correct designing of
mining works using blasting operations. For measuring of mentioned parameters, the methods and devices of “Dolgov Bomb” and Becker test are used. But this method is applicable for study of high-sensitivity explosives. Same time, the renunciation of high-sensitivity explosives, such as TNT, RDX and etc., should be noted over last years, because of the emission of toxic gases in air by large quantities at their use, resulting to the negative ecological impact. As an alternative, for national mining industry, the large-scale use of emulsion explosives and the explosives, prepared on the basis of colloidal blasting powders, liberated from low-sensitivity and expired military-engineering items, was carried out. Above-mentioned explosives call for the study for determination of their main characteristics, since it is well-known that they are characterized by large crisis diameter and correspondingly – by large crisis mass. In particular, the charge in 50 grams (mass of samples for testing in Dolgov Bomb) prepared from low-sensitive above mentioned explosives, don’t detonate. So, for detonation the considerable large mass of the tested charge is necessary, therefore determination of their characteristics by the use of Dolgov and Becker bombs is impossible. Based on above-mentioned, the necessity appeared in elaboration of the device/explosion chamber and non-conventional set-up for determination of main characteristics of the explosives prepared on the basis of low-sensitivity emulsion explosives and colloidal explosive powders.

2. Calculations and modelling
The method is based on the temperature increase in calorimetric liquid at the expense of heat release after explosion. In the detonation chamber, located in the liquid, the amount of liquid increased heat is equivalent to the energy of chemical transformation of the explosive (internal energy). This fact allows the determination of all necessary thermodynamic parameters. Thermal effect of the reaction of explosive transformation is indicative of its breaking energy. Mechanical work of the explosion is performed by the gaseous product of the transformation which is heated up to high temperature and expanded at the expense of released heat. Correspondingly the increased volume of the gases, formed at the expense of explosion heat, performs fougasse and brisant action of the explosive.

Along with it, it is well-known that explosion effect is mainly determined by explosion heat of the charge, since the coefficient of the release of explosive thermal energy depends on detonation velocity. Therefore, the latter, together with the thermal energy, represents the main characteristic parameter of the explosive. For modern fine-grained powder explosives the determination of explosion heat (thermal energy) is carried out by experimental manner by the use of detonation chamber. This fact also creates the necessity of its manufacturing.

The use of modern, low-sensitivity industrial explosives, together with the determination of their detonation and physical-chemical characteristics, also requires the establishment of their sensitivity at the action of external factors. Qualitative estimation of the explosive involves the determination of their main characteristic physical and chemical parameters in theoretical, laboratory and polygon conditions and the analysis of the result.

Theoretical calculations are verified on the basis of laboratory data and laboratory ones – on the basis of the results of industrial – polygon tastings. For solving of above-listed tasks the manufacturing of calorimetric equipment with new parameters was planned. These data will form the foundation for creation of industrial explosives of new class and for determination of safe conditions of their use. Metallic explosion chamber represents unique equipment, which allows the localization of the energy of explosive material in the closed space for determination of its main characteristic parameters and for their technological use.

Designing of ergonometric explosion chamber/equipment requires the optimization of the mass of its envelope metal and of geometrical sizes. Mentioned problem was widely studied by several authors in the course of which simple analytical relation between the masses of metallic envelope of explosion chamber
are determined [2-10]. For calculations of thickness of chamber’s envelope, the following expressions, obtained by authors of paper [11] were applied in this study:

\[ \delta = \frac{K}{R} (1), \quad K = \frac{ME\sqrt{2Q}}{\pi \rho d [\sigma]} \]  

(1)

\[ [\sigma] = \frac{ME\sqrt{2Q}}{\pi \rho \delta R \alpha} \]  

(2)

For reliability of the chamber under cyclic loadings the condition must be satisfied:

\[ \sigma (eq) \leq [\sigma] \]  

(3)

where,
- \( \delta \) - thickness of the envelope of chamber
- \( \sigma \) (eq) - equivalent stress in the envelope of explosion chamber
- \( \rho \) - density of the chamber/envelope material
- \( E \) - module of elasticity of the chamber material
- \( \alpha \) - sound speed in the chamber material
- \( M \) – mass of the charge for cylindrical mode
- \( Q \) - specific explosion heat of charge

On the basis of above-mentioned methodology, the thickness of metallic detonation chamber of cylindrical geometry was calculated for the following conditions/designing parameters:

- height – 0.75 m;
- internal diameter – 0.4 m;
- external diameter – 0.7 m;
- coverage (roof) height – 0.15 m;
- volume of detonation chamber comprises – 75 ltr;
- area of chamber internal surface – 1 m²;
- Total area of the surface of 3 channels/holes – 0.0038 m²;
- material for the envelope of explosion chamber – steel AISI 1020
- Explosive Material 1kg TNT equivalent

Calculated thickness’ of chamber envelope is: \( \delta = 0.15 \) m;

For validation and optimization of theoretical results, stress-deformed state of explosion loaded chamber was evaluated by computer modelling using ANSYS Autodyn simulations. Chamber geometry for simulation is shown on Figure 1. Explosive charge of 1kg TNT located in center of chamber. Simulations were performed for different parameters of chamber (size; internal diameter; material etc.). The thickness of envelope was varied between: \( \delta = 0.10 \) – 0.20 m.

The Von Mises stress rates and approach was applied as a criterion for determination of chamber resistivity under internal explosion. Criterion suggests that the yielding of materials begins when the second deviatoric stress invariant reaches a critical value. Prior to yield, material response is assumed to be elastic.
Figure 1. Scheme for computer simulation of explosion chamber

The results of simulation are presented on Figure 2 and Figure 3.

Starting of Explosion
Beginning of Rupture
c)  
![Rupture image]

Figure 2. The distribution of stresses in chamber with wall thickness $\delta = 0.10\text{m}$: a) $T=0.05\text{ ms}$; b) $T=0.12\text{ms}$; c) $T=1.57\text{ms}$; d) Von Mises stress – Time history (stress development schedule).

![Stress distribution image]

a) Starting of Modelling

b) End of modelling

Figure 3. The distribution of stresses in chamber with wall thickness $\delta = 0.15\text{m}$: a) $T=0.5\text{ ms}$; b) $T=4\text{ms}$; Chamber is stable to stresses

3. Results and discussions

Based on the study the design parameters of equipment for determination of energetic and technological characteristics of low sensitive explosives was determined. Detonation chamber of our design allows the
detonation initiation in tested charge by means of intermediate detonator the share of which in the volume of total charge is relatively negligible on the basis of the possibility of the increase of the mass of sample charge. From all above-mentioned the practical importance of the work is beyond question allowing the creation and use of eco-safe and high class explosives of new type.

4. Conclusions

- Theoretical calculations were performed for determination of optimal design parameters of equipment for determination of energetic, detonation and technological characteristics of low sensitive explosive substances;
- Obtained theoretical results was validated by computer modelling using ANSYS Autodyn simulations;
- This is preliminary results of research work which will be prolong.
- Detonation chamber is under production process at the factory and the experimental data from the explosives tests will be presented in the future.

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