Impact sensitivity test of liquid energetic materials

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Abstract. This paper presents new experimental method for sensitivity evaluation at the impact. A large number of researches shown that the probability of explosion initiating of liquid explosives by impact depends on the chemical nature and the various external characteristics. But the sensitivity of liquid explosive in the presence of gas bubbles increases many times as compared with the liquid without gas bubbles. In this case local chemical reaction focus are formed as a result of compression and heating of the gas inside the bubbles. In the liquid as a result of convection, wave motion, shock, etc. gas bubbles are easily generated, it is necessary to develop methods for determining sensitivity of liquid explosives to impact and to research the explosives ignition with bubbles. For the experimental investigation, the well-known impact machine and the so-called appliance 1 were used. Instead of the metal cup in the standard method in this paper polyurethane foam cylindrical container with liquid explosive was used. Polyurethane foam cylindrical container is easily deforms by impact. A large number of tests with different liquid explosives were made. It was found that the test liquid explosive to impact in appliance 1 with polyurethane foam to a large extent reflect the real mechanical sensitivity due to the small loss of impact energy on the deformation of the metal cup, as well as the best differentiation liquid explosive sensitivity due to the higher resolution method.

1. Introduction
Well known, none of the methods for determining sensitivity liquid explosive to impact can not give an absolute evaluation of the safety. For liquid explosives systems there are features associated with the aggregate state. One problem is the reliable storage of the test sample liquid explosive in the area of mechanical action in the preparation and testing. Metal cup, filled with liquid explosive is used in the standard method [1]. Significant influence on the accuracy and interpretation of the results has the fact that a significant part of the impact energy is expended on the deformation of the cup. Mechanism of initiation is also important. If the gas bubbles exist or arise in the liquid explosive, the initiation occurs at lower energies strike. Focuses of heating and ignition in this case are the result of the compression and heating of the gas in the bubbles. The most correct way out is to improve the complex test sensitivity methods and a detailed theoretical and experimental study explosive initiating by impact. In [2] is developed a mathematical model of thermal and hydrodynamic processes that occur during compression of gas bubbles in liquid explosive.

2. Experimental
Calculations showed that the presence of bubbles can significantly reduce the energy of the external impact for initiation. For the simulation of bubble structure in this paper to determine liquid
explosive sensitivity to impact as a container (instead of the cup) to accommodate liquid explosive is used cylinder of polyurethane foam. Cylinder of polyurethane foam has a highly developed porosity, foam is inert and insolubility in most liquid explosives and foam is easily deformed by mechanical actions. Impact machine (figure 1) and roller device (figure 2) were used for determining sensitivity liquid explosive.

**Figure 1.** Impact machine.

**Figure 2.** Roller device.

1-coupling; 2,4-upper and bottom rollers; 3- polyurethane foam with liquid explosive.

3. Results and discussion

Tests were made with elastic impact (1), polyurethane foam (1-p) and 1-c (with cup) to estimate the total energy loss. Beat with a load of 10kg was performed with heights ranging 100-600mm. Quantification was performed according to the following:

\[ E_{ad} = E_{im} - E_{re} \]

where \( E_{ad} \) - the loss or deformation of the foam cap and impact machine; \( E_{im} \) - the impact energy; \( E_{re} \) - the rebound energy. \( E \) is calculated from the relationship:

\[ E = mgh, \]

where \( m \) the weight of the load; \( h \) - the height of a reset or rebound.

Obtained experimental data given in table 1 and figure 2.

**Table 1.** The total energy loss in the device impact machine and roller devices 1, 1-p and 1-c.

| Drop height, \( h \), mm | Impact energy, \( E_{im}, J \) | Energy losses |
|-------------------------|-------------------------------|--------------|
|                         |                               | 1            | 1-p          | 1-c          |
| 100                     | 9,81                          | 2,45         | 3,43         | 8,83         |
| 200                     | 19,62                         | 4,42         | 5,40         | 12,26        |
| 400                     | 39,24                         | 9,81         | 10,79        | 19,52        |
| 600                     | 58,86                         | 18,64        | 20,60        | 27,96        |

In device 1-p used foam cylinder with a diameter of 10 mm and a height of 5 mm.
The data in table 1 and figure 3 indicate that at low drop height (100mm), the energy loss in devices 1, 1-p, and 1-c are 25%, 35%, and 90% of the impact energy, respectively. At high drop height, energy loss in 1-p is almost equal to elastic impact energy (the difference is 2.5-3.3%), while the deformation of the cap as 25-40% of the energy expended impact.

Thus, we can conclude that the foam contributes in 4-8 times less distortion during impact as compared with the cap.

Experimental studies on the absorption capacity of the foam were performed on cylinders with a diameter of 10 mm and a height of 10mm 2,4,5,8, 10mm. These results are summarized in table 2.

| Height of the cylinder of foam, mm | 2   | 4   | 5   | 8   | 10  |
|----------------------------------|-----|-----|-----|-----|-----|
| Volume of a cylinder of foam, m³10⁻⁶ | 0,157 | 0,314 | 0,393 | 0,628 | 0,785 |
| Weight foam cylinder, mg         | 6   | 13  | 16  | 25  | 32  |
| Quantity of a liquid, nitroglycerine, mg | 245 | 490 | 612 | 980 | 1225 |

The data in table 2 show that the cylinder has a height of 2mm foam has full capacity to absorb about 250mg. However, soft polyurethane has two types of pores: closed and reported. The reported pores can lead to a gradual filtering of the test sample from liquid explosive foam cylinder. In this regard, studies have been made with foam cylinders with benzene, toluene, and glycerol. In the experiments we used samples of foam height from 2 to 10mm. With the help of filter paper and glass, on which
were placed foam cylinders, visually with permeability was determined. The results are shown in table 3.

### Table 3. Filtration time.

| Quantity of a liquid, mg | Filtration time (h, m, s) |
|-------------------------|--------------------------|
|                         | Height of the foam cylinder (mm) |
|                         | 2  | 4  | 5  | 8  | 10 |
| 20                      | 11m | >12h | >12h | >12h | >12h |
| 30                      | 10m | >12h | >12h | >12h | >12h |
| 40                      | 55s | >12h | >12h | >12h | >12h |
| 50                      | 50s | >12h | >12h | >12h | >12h |
| 75                      | 35s | 28min | >12h | >12h | >12h |
| 100                     | 25s | 4min | 10min | 14min | >12h |

As shown by the test results, there are two kinds of through filtering (time expiration) in dependence on the height and the weight of the liquid foam. In the first case, for large sample (40-100mg) and low height foam cylinder (2mm) filtering is done in a very short time, almost commensurate with the time of making the liquid sample (25-60s). It can be assumed that the height of the cylinder of 2 mm, there is a significant number of through pores communicating height, which due to the gravitational force and the wettability is so rapid filtration.

In the second case was observed penetrating filtration over a longer second time (4-28min.) Thus, the data in Table 3 indicate that for tests carried liquid explosive sample weighing between 50 to 75 mg is optimal foam cylinder height of about 5mm.

Distribution pattern of the liquid sample weighing 75 mg in a cylinder of foam was obtained. It is evident that with the known assumption, this distribution of liquid in a foam cylinder can be considered cylindrical. In this case, the spot diameter is about 6 mm and the depth of penetration of the 3.5-4 mm.

Test using a mass 10 kg can not determine the lower limits of most studied liquid explosive. Therefore, to determine the relative frequency of the lower explosion limit of the experiments, we performed experiments with a 2-kg mass, whose results are shown in table 4.

### 4. Conclusion

Determination of explosion frequency liquid explosive with the construction of complete curves performed on the impact machine and the use of 10kg weight. Experiments were made for different liquid explosives. Experimental data show that the results of tests in 1-p provide an opportunity to get the full frequency curve explosions. The curves have a particular characteristic S-shaped appearance. Also, as in the tests of solid explosives, the difference in sensitivity at the upper limit liquid explosive explosion frequency significantly higher than in the lower limit. As in the case of solid explosives is crossing curves explosion frequency different liquid explosives. Analysis of the results of determining the lower limit of explosions in cups and device 1-p leads to several conclusions.

Firstly, there is the sharp increase in the sensitivity in device 1-p compared with trials in cups.

### Table 4. The lower limit of explosion frequency LHE in device 1-c and 1-p.

| LHE       | 1-c | 1-p |
|-----------|-----|-----|
| Nitroglycerine | Drop height $H_0$, mm | Impact energy, J | Drop height $H_0$, mm | Impact energy, J |
|           | 120 | 2,35 | 20 | 0,39 |
For example, the impact energy corresponding to the lower limit for the particular explosions for nitroglycerine has decreased in 6 times. Absolute values decreased about 2-3 J. This can be attributed to loss of impact energy to deformation of the cap, which is almost identical to the data, where the experimental data loss (40-90%) depending on the drop height.

The method of determining the sensitivity of liquid explosive in device 1-p has a significantly higher resolution than standard. For example, explosion parameters for nitroglycerine when tested with a cap differ in differ from the results of tests in 1-p in 6.3 times. Thus, we can conclude that the test liquid explosive to strike in 1-p to a large extent reflect the real sensitivity to mechanical stress due to the exclusion of loss of impact energy on the deformation of the metal cap, as well as the best differentiation liquid explosive sensitivity due to the higher resolution of the method.

References
[1] "Standard Test Method for Drop-Weight Sensitivity of Liquid Monopropellants", ASTM Designation D2540-93 (2001)
[2] Tyutyaev A, Dolzhikov A, Zvereva I 2014 Phenomenological models of explosive systems initiation at mechanical influences Proceedings of 17 Seminar on "New Trends in Research of Energetic Materials" (Pardubice, Czech Republic) pp 428-433