EFFECT OF HEATING ON THE CLEAVAGE FRACTURE OF CERTAIN EXPLOSIVE COMPounds

V. K. Golubev, S. A. Novikov, and Yu. S. Sobolev

Results are presented from an experimental study of the effect of heating on the cleavage fracture of four explosive compounds based on hexogen and octogen. The loads that are critical in terms of collision velocity and pressure in the compressive loading pulse are determined. Macroscopic cleavage fracture of the specimens occurs above these loads. It is shown that the type and percentage content of the binder influence the paths of the temperature dependences of these loads.

Questions relating to the dynamic strength and fracture of explosives have not received the attention they deserve in the scientific literature. As far as we know, only the studies [1, 2] have addressed this subject. In [1], data on dynamic strength in uniaxial tension was obtained for PETN and four compositions based on octogen. The authors of [2] studied the cleavage fracture of high-energy solid rocket fuel, i.e., an explosive compound that had actually been stabilized. However, the need to solve certain applied problems connected with the use of explosives under extreme conditions and an interest in the scientific aspects of the subject have motivated us to undertake the present investigation. Here, we attempt to explain the effect of heating to 150°C on the resistance of certain explosives to cleavage fracture when subjected to shock loading.

We studied four explosives — two based on hexogen and two based on octogen. The first two were the widely used TG50/50 and the explosive GTK-70. The latter contains 30% tetryl-colloxylin binder in a 2/1 ratio. The other two explosives were OTK-90, containing 10% of the same binder, and explosive OFA-6 (the binder included 6% fluoroplastic and 1% short antipyrene fibers). The specimens were made by pressing (dimensions 240 × 4 mm, density $\rho_3 = 1.65, 1.72, 1.85$, and 1.87 g/cm$^3$, respectively) and tested by the method in [3]. The specimens were affixed to a copper screen 12 mm thick and shock-loaded by the impact of a 4-mm-thick aluminum plate against the screen. The plate was previously accelerated to the necessary velocity $w$. Heating was done with an electric heater, while temperature $T$ was recorded with a chromel-copel thermocouple.

In the tests, we determined the critical collision velocity above which the specimen would undergo macroscopic failure by cleavage. We used the following formula from acoustics to change over from the collision velocity to the pressure $p$ in the loading pulse

$$p = \frac{2\rho_3c_3w}{\left(1 + \frac{\rho_2c_2}{\rho_1c_1}\right)\left(1 + \frac{\rho_3c_3}{\rho_2c_2}\right)}.$$ 

Here, as bulk sonic velocity $c$, we used the corresponding coefficients in the relations between the mass and wave velocities $D = c + \lambda u$. For the material of the striker, $\rho_1 = 2.7$ g/cm$^3$ and $c_1 = 5.3$ km/sec. The characteristics of the screen material were $\rho_2 = 8.9$ g/cm$^3$ and $c_2 = 4.0$ km/sec. We used the values $c_3 = 2.7, 2.4, 2.7$, and 2.5 km/sec for explosives TG50/50, GTK-70, OTK-90, and OFA-6, respectively. The densities of these substances $\rho_3$ were given above. The characteristic loading time was estimated to be 1.5 μsec, which corresponded to the time of circulation of the acoustic wave in the aluminum striker-plate.

The experimental results are shown in Fig. 1, where three gradations in the condition of the specimen after loading were provisionally established in accordance with the specific loading conditions. In the case of complete cleavage fracture,
Fig. 1. Effect of temperature on the cleavage fracture of TG50/50 (a), OTK-90 (b), OFA-6 (c), and GTK-70 (d). 1) complete cleavage fracture; 2) partial macroscopic cleavage fracture; 3) preservation of the macroscopic integrity of the specimen.

Fig. 2. Outward appearance of specimens of GTK-70 that underwent partial (a) ($T = 75^\circ C$, $p = 150$ MPa) and complete (b) ($T = 20^\circ C$, $p = 220$ MPa) cleavage fracture.

all or a large part of the rear surface of the specimen separated from the rest of the material. An increase in loading rate led to fracture of the specimen into a substantial number of fragments. In the case of partial macroscopic cleavage, the rear part of the specimen surface separated from the bulk of the specimen.

Figure 2 shows the outward appearance of the GTK-70 specimens after fracture. The third gradation corresponds to preservation of the macroscopic integrity of the specimen. Especially at room temperature, this state might include cracks on the specimen surface.

Except for low-strength TG50/50, we could roughly distinguish the regions corresponding to gradation three and possible macroscopic cleavage fracture in all of the explosives within the range of loading parameters indicated in Fig. 1. An examination of the results shows the anomalous behavior of TG50/50 and GTK-70, the latter containing the largest amount of low-melting trotyl-colloxylin binder. For example, TG50/50 loaded at room temperature fractured into a sizable number of small fragments, but the same compound loaded at $T = 90^\circ C$ had a form similar to that depicted in Fig. 2a. The compound GTK-70 shock-loaded at $T = 150^\circ C$ by a pressure of 330 MPa appeared somewhat deformed and flattened out but main-