CHEMICAL PEAK BRAKE CURVE OF DETONATING PLASTIC BONDED TATB

V. I. Tarzhanov, A. V. Vorobyov, D. P. Kuchko, M. A. Ralnikov, R. V. Komarov, and G. G. Bondarchuk

Russian Federal Nuclear Center — Zababakhin All-Russia Research Institute of Technical Physics, PO Box 245, 13 Vasilieva Str., Snezhinsk, Chelybinsk Region 456770, Russian Federation

Abstract: The chemical reaction zone (chemical peak) in detonating plastic bonded TATB has been studied. Velocities of Al, Cu, Ni, Mo, and Ta 0.03–0.4-millimeter thick foils installed on the surface of the high explosive (HE) charge under study as well as detonation profiles at the boundary with lithium fluoride, sapphire, and PMMA (plexiglass) windows were recorded. The experimental points associated with braking of the detonation front on the foils and windows made of different materials have been approximated on coordinates pressure – particle velocity (P–u) of a unified curve named by the authors as the chemical peak brake curve. Intersection of this curve with the wave beam permitted the authors to obtain the state in HE at the Neumann peak $P_N = 36.6$ GPa and $u_N = 2.52$ km/s. The curves associated with the HE "instantaneous" release from the braking state have been constructed. The authors put forward a hypothesis for decomposition of the studied HE at the detonation front and near it with the significant energy release at the brake pressures above 65 GPa. This hypothesis claims that below the threshold, the HE remains unreacted both on the reflected wave front and under "instantaneous" release from the braking state.

Keywords: high explosive (HE); plastic bonded TATB; detonation; chemical peak (Neumann peak); laser interferometer diagnostics; Photonic Doppler Velocimetry (PDV); barrier method

DOI: 10.30826/CE20130311

Figure Captions

Figure 1 Experimental setup (*a*) and foils location on the HE surface around the window (*b*): *1* — electric detonator; *2* — socket; *3* — centralizer; *4* — lens charge; *5* — grain TG55 $\varnothing 120 \times 10$ mm; *6* — studied HE - plastic bonded TATB (PBT); *7* — carrier of ferrules; *8* — clamp; *9* — window $\varnothing 40 \times 20$ mm; *10* — measurement system; *11* — PDV ferrules; *12* — "combined" optic fiber head; and *13* — foils

Figure 2 Velocity profiles of the various-thickness Al foils: *1* — $\Delta = 0.06$ mm; *2* — 0.10; *3* — 0.20; and *4* — $\Delta = 0.30$ mm

Figure 3 t, x-diagram of the wave circulations in the foil

Figure 4 Velocities of Al (*a*), Cu (*b*), Ni (*c*), Mo (*d*), and Ta (*e*) foils recorded on the first W_1 (*1*), second W_2 (*2*), and third W_3 (*3*) jumps vs. their thicknesses Δ. Finding of W_{01}, W_{02}, and W_{03}

Figure 5 P, u state diagrams attributed to the wave interactions in the foil materials and the studied HE: 1, 2, and 3 — free surface velocities of Al foils on the first, second, and third jumps — $W_{01\mathrm{Al}}$, $W_{02\mathrm{Al}}$, and $W_{03\mathrm{Al}}$ by its thickness $\Delta \to 0$; 4, 5, and 6 — the same is for Cu foil — $W_{01\mathrm{Cu}}$, $W_{02\mathrm{Cu}}$, and $W_{03\mathrm{Cu}}$; 7, 8, and *9* — the same is for Ni foil — $W_{01\mathrm{Ni}}$, $W_{02\mathrm{Ni}}$, and $W_{03\mathrm{Ni}}$; 10, 11, and *12* — the same is for Ta foil; 13, 14, and 15 — the same is for Mo foil; 16, 19, 22, 25, and 28 — states emerged on Al, Cu, Ni, Mo, and Ta Hugoniots when the Neumann state enters the foil; 17, 20, 23, 26, and 29 — the states at the "HE–foil" interface emerged after the first wave circulation along Al, Cu, Ni, and Mo foils; and 18, 21, 24, 27, and 30 — the same is after the second circulation along the foil

Figure 6 Four velocity profiles recorded in four PDV channels in one experiment ($H_{\mathrm{PBT}} = 60$ mm) with the sapphire window (*a*); and seven velocity profiles recorded in seven PDV channels with LiF window in two experiments ($H_{\mathrm{PBT}} = 40$ mm) (*b*)

Figure 7 Velocity profiles recorded in PDV (*1*) and VISAR (*2*) channels with a plexiglass window in one experiment ($H_{\mathrm{PBT}} = 60$ mm)

Figure 8 P, u-diagrams of the states emerged in PBT under braking on Al, Cu, and Ni foils and on the sapphire (Al_2O_3), LiF, and plexiglass windows. Chemical peak break curve: signs — experimental points indicated in Tables 1 and 2 (*1* — [2]; *2* — [4]; *3* — [6]; and *4* — present work)

Table Captions

Table 1 Calculated values of W_{01}, W_{02}, and W_{03}, u_{01}, u_{02}, and u_{03}, and P_{01}, P_{02}, and P_{03}

Table 2 Maximum velocity and pressure values at the plasticized TATB-window boundary

References

1. Gibbs, T. R., and F. Popolato, eds. 1980. *LASL explosive property data*. Los Alamos ser. on dynamic material properties. Berkeley, Los Angeles, London: University of California Press. 481 p.
2. Sheffield, S. A., D. D. Bloomquist, and C. M. Tarver. 1984. Subnanosecond measurements of detonation fronts in solid high explosives. *J. Chem. Phys.* 80(8):3831–3844.
3. Dick, J. J., C. A. Forest, J. B. Ramsay, and W. L. Seitz. 1988. The Hugoniot and shock sensitivity of a plastic-bonded TATB explosive PBX 9502. *J. Appl. Phys.* 63(10):4881–4888.
4. Shorokhov, E. V., and B. V. Litvinov. 1993. Udarnaya szhimaemost' vzryvchatykh kompozitsiy na osnove TATB v diapazone davleniy ot 0.1 do 40 GPa [Shock compressibility of the TATB-based explosive compositions for pressure range from 0.1 to 40 GPa]. *Khim. Fiz.* 12(5):722–723.
5. Lubyatinsky, S. N., and B. G. Loboiko. 1998. Detonation reaction zones of solid explosives. *12th Symposium on Detonation Proceedings*. Snowmass, CO.
6. Loboiko, B. G., and S. N. Lubyatinsky. 2000. Reaction zones of detonating solid explosives. *Combust. Explo. Shock Waves* 36(6):716–733.
7. Fedorov, A. V. 2005. Parametry pika Neimana i struktura fronta detonatsionnoy volny kondensirovannykh vzryvchatykh veshchestv [Neumann peak parameters and detonation wave front structure in condensed explosives]. *Khim. Fiz.* 24(10):13–21.
8. Kolesnikov, S. A., and A. V. Utkin. 2007. Nonclassical steady-state detonation regimes in pressed TNETB. *Combust. Explo. Shock Waves* 43(6):710–716.
9. Fedorov, A. V., A. L. Mikhailov, L. L. Antonyuk, D. V. Nazarov, and S. A. Finyushin. 2011. Determination of parameters of detonation waves in PETN and HMX single crystals. *Combust. Explo. Shock Waves* 47(5):601–605.
10. Fedorov, A. V., A. L. Mikhailov, L. L. Antonyuk, D. V. Nazarov, and S. A. Finyushin. 2012. Opredelenie parametrov zony khimicheskoy reaktsii, sostoyaniy pika Neimana i Chepmena–Zhuge v gomogennykh i geterogennykh vzryvchatykh veshchestvakh [Determination of chemical reaction zone parameters, Neumann peak parameters and the state in the Chapman–Jouguet plane in homogeneous and heterogeneous high explosives]. *Conference (International) "12th Zababakhin Scinetific Talks": Book of Abstracts*. Snezhinsk: RFNC-VNIITF. P. 94.
11. Kozlov, E. A., V. I. Tarzhanov, I. V. Telichko, A. V. Vorobyov, K. V. Levak, V. A. Matkin, A. V. Pavlenko, C. N. Malyugina, and A. V. Dulov. 2012. Struktura zony reaktsii detoniruyushchego melkozernistogo TATB [Reaction zone structure for the detonating fine-grained TATB]. *Conference (International) "Shock Waves in Condensed Matter."* Kiev, Ukraine: Interpess LTD. 58–60.
12. Kozlov, E. A., V. I. Tarzhanov, I. V. Telichko, A. V. Vorobiev, K. V. Levak, V. A. Matkin, D. P. Kuchko, M. A. Ralnikov, D. S. Boyarnikov, A. V. Pavlenko, S. N. Malyugina, and A. V. Dulov. 2013. Struktura zony reaktsii TATB pri normal'noy i pereszhatoy detonatsii [TATB reaction zone structure under normal and overdriven detonation]. *Conference (International) "15th Khariton Topical Scientific Readings:" Book of Abstracts*. Sarov: RFNC-VNIIEF. 31–32.
13. Duff, R. E., and E. F. Houston. 1955. Measurement of the Chapman–Jouguet pressure and reaction zone length in a detonating high explosive. *J. Chem. Phys.* 23:1268–1273.
14. Dremin, A. N., and P. F. Pokhil. 1961. Issledovanie zony khimicheskoy reaktsii trotila [Study of TNT chemical reaction zone]. *Russ. J. Phys. Chem. A* 34(11):2561.
15. Zel'dovich, Ya. B., and A. S. Kompaneets. 1955. *Teoriya detonatsii* [Detonation theory]. Moscow: Gostekhizdat. 268 p.
16. Jackson, R. K., L. G. Green, R. Barlett, *et al.* 1976. Initiation and transition regularities in TATB. *6th Symposium (International) on Detonation Proceedings*. Coronado, CA.
17. Green, L. G., C. M. Tarver, and D. J. Erskine. 1989. Reaction zone structure in supracompressed detonating explosives. *9th Symposium (International) on Detonation Proceedings*. Portland, OR.
18. Aminov, Yu. A., N. S. Es'kov, Yu. R. Nikitenko, and G. N. Rykovanov. 1998. Calculation of the reaction-zone structure for heterogeneous explosives. *Combust. Explo. Shock Waves* 34(2):230–233.
19. Grebenkin, K. F., ed. 2017. *Fizicheskie modeli detonatsii geterogennykh kristallicheskikh vzryvchatykh veshchestv* [Physical models of heterogeneous crystalline explosives]. Snezhinsk: RFNC-VNIITF. 290 p.
20. Aminov, Yu. A., M. M. Gorshkov, V. T. Zaikin, G. V. Kovalenko, Yu. R. Nikitenko, and G. N. Rykovanov. 2002. Deceleration of detonation products of a TATB-based high explosive. *Combust. Explo. Shock Waves* 38(2):235–238.
21. Strand, O. T., D. R. Goosman, C. Martinez, T. L. Whitworth, and W. W. Kuhlow. 2006. A novel system for high speed velocimetry using heterodyne techniques. *Rev. Sci. Instrum.* 77:083108.
22. Kozlov, E. A., V. I. Tarzhanov, I. V. Telichko, D. G. Pankratov, D. P. Kuchko, and M. A. Ralnikov. 2014. O sovmeshchenii metodik opticheskogo rychaga i lazerno-geterodinnoy dlya izucheniya dinamicheskikh svoystv konstruktsionnykh materialov [On combining the optical lever and laser heterodyne techniques to study dynamic properties of structural materials] *Conference (International) "12th Zababakhin Scientific Talks": Book of Abstracts*. Snezhinsk. RFNC-VNIITF. P. 229.
23. Trunin, R. F., ed. 2006. *Eksperimental'nye dannye po udarno-volnovomu szhatiyu i adiabaticheskomu rasshireniyu kondensirovannykh veshchestv* [Experimental data on

shock-wave compression and adiabatic expansion of condensed materials]. Sarov: RFNC-VNIIEF. 531 p.

24. Jensen, B. J., D. B. Holtkamp, and P. A. Rigg. 2007. Accuracy limits and window corrections for photon Doppler velocimetry. *J. Appl. Phys.* 101:013523.

25. Erskine, D. 1993. High pressure Hugoniot of sapphire. *High Pressure Science and Technology: Joint International Association for Research and Advancement of and American Physical Society Topical Group on Shock Compression of Condensed Matter Conference Proceedings*. Eds. S. C. Schmidt, J. W. Shaner, G. A. Samara, and M. Ross. Colorado Springs, CO. 141–143.

26. Bouyer, V., P. Hebert, M. Doucet, L. Decaris, and L. Terzulli. 2012. Experimental measurements of the chemical reaction zone of TATB and HMS based explosives. *AIP Conf. Proc.* 1426:209–212.

27. Tang, P. K., W. W. Anderson, J. E. Fritz, R. S. Hixson, and J. E. Vorhman. 2002. A study of the overdriven behaviors of PBX 9501 and PBX9502. *12th Symposium (International) on Detonation Proceedings*. San Diego, CA.

28. Dremin, A. N. 1995. K teorii detonatsii [Toward detonation theory]. *Khim. Fiz.* 14(12):22–40.

Received July 9, 2020

Contributors

Tarzhanov Vladislav I. (b. 1940) — Candidate of Science in physics and mathematics, leading research scientist, Zababakhin All-Russia Research Institute of Technical Physics, PO Box 245, 13 Vasilieva Str., Snezhinsk, Chelybinsk Region 456770, Russian Federation; v.i.tarzhanov@vniitf.ru

Vorobiev Akim V. (b. 1971) — head of group, Zababakhin All-Russia Research Institute of Technical Physics, PO Box 245, 13 Vasilieva Str., Snezhinsk, Chelybinsk Region 456770, Russian Federation; v.i.tarzhanov@vniitf.ru

Kuchko Dmitriy P. (b. 1984) — head of department, Zababakhin All-Russia Research Institute of Technical Physics, PO Box 245, 13 Vasilieva Str., Snezhinsk, Chelybinsk Region 456770, Russian Federation; d.p.kuchko@vniitf.ru

Ralnikov Mikhail A. (b. 1987) — research engineer, Zababakhin All-Russia Research Institute of Technical Physics, PO Box 245, 13 Vasilieva Str., Snezhinsk, Chelybinsk Region 456770, Russian Federation; v.i.tarzhanov@vniitf.ru

Komarov Roman V. (b. 1991) — research engineer, Zababakhin All-Russia Research Institute of Technical Physics, PO Box 245, 13 Vasilieva Str., Snezhinsk, Chelybinsk Region 456770, Russian Federation; v.i.tarzhanov@vniitf.ru

Bondarchuk Galina G. (b. 1947) — senior research scientist, Zababakhin All-Russia Research Institute of Technical Physics, PO Box 245, 13 Vasilieva Str., Snezhinsk, Chelybinsk Region 456770, Russian Federation; v.i.tarzhanov@vniitf.ru