EVALUATION OF ACCELERATION ABILITY OF EXPLOSIVE COMPOSITIONS CONTAINING BIS-(2-DIFLUOROAMINO-2,2-DINITROETHYL)NITRAMINE

M. N. Makhov

N. N. Semenov Federal Research Center for Chemical Physics of the Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation

Abstract: The possibilities of increasing the acceleration ability (AA) of energetic materials due to creation of compositions combining explosives with positive and negative oxygen balance (OB) are analyzed. At calculations, the BFADEN compound (bis-(2-difluoroamino-2,2-dinitroethyl)nitramine) containing oxygen and fluorine in the molecule was considered as the main explosive with positive OB. The function of the explosive fuel was performed by powerful substances HMX, CL-20, and FTDO which have negative OB. It follows from the calculation that the AA of the specified explosives with negative OB noticeably increases when BFADEN is added to them. An additional increase in AA should be expected when an aluminum additive is incorporated into such compositions. In this case, the AA (under the conditions of the M-40 procedure) for aluminized compositions with BFADEN can reach a record value of 1,10 in relation to HMX.

Keywords: acceleration ability; explosive; oxygen balance; heat of explosion; aluminum

DOI: 10.30826/CE25180413 **EDN:** THBEZO

Figure Captions

Figure 1 Acceleration ability of the mixtures of HMX with explosive oxidizers depending on the mass fraction of oxidizer: *1* — BFADEN; *2* — ONPP; *3* — BTEN; *4* — HNF; *5* — ADN; and *6* — DNG. Dashed lines — the compositions with the Al additive

Figure 2 Acceleration ability of the mixtures for the compositions based on CL-20 (*a*) and on FTDO (*b*): *1* — BFADEN; *2* — ONPP; *3* — BTEN; *4* — HNF; *5* — ADN; and *6* — DNG. Dashed lines — the compositions with the Al additive

Table Captions

Table 1 Acceleration ability of explosives

Table 2 Acceleration ability of explosive compositions

Table 3 Initial parameters of explosives

Acknowledgments

The work was carried out within the framework of the Fundamental Scientific Research Program of the Russian Federation "Chemical Physics of Oxidation, Combustion, and Explosion," registration No. 1024040200065-4, and had budgetary funding.

References

1. Orlenko, L. P., ed. 2002. *Fizika vzryva* [Physics of explosion]. 3rd ed. Moscow: Fizmatlit. Vol. 1. 832 p.
2. Zhernokletov, M. V., ed. 2003. *Metody issledovaniya svoystv materialov pri intensivnykh dinamicheskikh nagruzkakh* [Methods for studying the properties of materials under intense dynamic loads]. Sarov: RFNC-VNIIF. 402 p.
3. Hardesty, D. R., and J. E. Kennedy. 1977. Thermochemical estimation of explosive energy output. *Combust. Flame* 28:45–59.
4. Hornberg, H. 1986. Determination of fume state parameters from expansion measurements of metal tubes. *Propell. Explos. Pyrot.* 11(1):23–31.
5. Finger M., E. Lee, F. H. Helm, B. Hayes, H. Hornig, R. McGuire, and M. Kahara. 1976. The effect of elemental composition on the detonation behavior of explosives. *6th Symposium (International) on Detonation Proceedings*. Coronado, CA. 710–722.
6. Gurney, R. W. 1943. The initial velocities of fragments from bombs, shells, grenades. Aberdeen, MD: Ballistic Research Laboratory. Report BRL 405. 13 p.
7. Kamlet, M. J., and M. Finger. 1979. An alternative method for calculating gurney velocities. *Combust. Flame* 34:213–214.
8. Koch, A., N. Arnold, and M. Estermann. 2002. A simple

relation between the detonation velocity of an explosive and its gurney energy. *Propell. Explos. Pyrot.* 27(6):365–368. doi: 10.1002/prep.200290007.

9. Danel, J.-F., and L. Kazandjian. 2004. A few remarks about the gurney energy of condensed explosives. *Propell. Explos. Pyrot.* 29(5):314–316. doi: 10.1002/prep.200400060.
10. Makhov, M. N., M. F. Gogulya, A. Yu. Dolgoborodov, M. A. Brazhnikov, V. I. Arkhipov, and V. I. Pepekin. 2004. Acceleration ability and heat of explosive decomposition of aluminized explosives. *Combust. Explo. Shock Waves* 40(4):458–466.
11. Gogulya, M. F., M. N. Makhov, M. A. Brazhnikov, A. Yu. Dolgoborodov, V. I. Arkhipov, A. N. Jigatch, I. O. Leipunskii, and M. L. Kuskov. 2008. Explosive characteristics of aluminized HMX-based nanocomposites. *Combust. Explo. Shock Waves* 44(2):198–212.
12. Davydov, V. Yu., and A. S. Gubin. 2011. Acceleration ability of high explosives and their mixtures with fuel additives. *Russ. J. Phys. Chem. B* 5(3):491–498. doi: 10.1134/S1990793111030183.
13. Makhov, M. N. 2018. Acceleration ability of aluminum-containing explosive compositions. *Russ. J. Phys. Chem. B* 12(2):258–265. doi: 10.1134/S1990793118020203.
14. Makhov, M. N. 2023. Razrabotka metoda otsenki metatel'noy sposobnosti vzryvchatykh veshchestv na osnove modeli Garni [Development of the method for evaluating the acceleration ability of high explosives on the basis of Gurney model]. *Goren. Vzryv (Mosk.) — Combustion and Explosion* 16(2):110–116. doi: 10.30826/CE23160210.
15. Makhov, M. N., and V. I. Arkhipov. 1989. Velocity of shell dispersion. *Combust. Explo. Shock Waves* 25(3):343–345.
16. Litvinov, B. V., A. A. Faynzil'berg, V. I. Pepekin, S. P. Smirnov, B. G. Loboyko, S. A. Shevelev, and G. M. Nazin. 1994. Povyshenie effektivnosti vysokoenergeticheskikh khimicheskikh veshchestv: vysokoenergeticheskie soedineniya, soderzhashchie v molekule aktivnyy ftor i aktivnyy kislorod [Increasing the efficiency of energetic chemical substances: Energetic compounds containing active fluorine and active oxygen]. *Dokl. Akad. Nauk* 336(1):67–68.
17. Pepekin, V. I., B. L. Korsunskii, and A. A. Denisaev. 2008. Initiation of solid explosives by mechanical impact. *Combust. Explo. Shock Waves* 44(5):586–590.
18. Pepekin, V. I. 1996. Development of high efficiency energetic explosives. *27th Annual Conference (International) of ICT Proceedings*. Karlsruhe. Paper 19. 7 p.
19. Pepekin, V. I., and S. A. Gubin. 2007. Propellant performance of organic explosives and their energy output and detonation velocity limits. *Combust. Explo. Shock Waves* 43(1):84–95.
20. Arkhipov, V. I., M. N. Makhov, and V. I. Pepekin. 1994. On detonations of composite explosives of the oxidizer–fuel type. *Sov. J. Chemical Physics* 12(12):2395–2399.
21. Gubin, S. A., V. V. Odintsov, V. I. Pepekin., and V. A. Schargatov. 1991. The effect of the detonation product composition on the velocity of explosively driven plates. *Sov. J. Chemical Physics* 8(5):1129–1144.
22. Ornellas, D. L. 1968. The heat and products of detonation of cyclotetramethylenetetranitramine, 2,4,6-trinitrotoluene, nitromethane, and bis(2,2-dinitro-2-fluoroethyl)formal. *J. Phys. Chem.* 72(7):2390–2394.
23. Zhukov, B. P., ed. 2000. *Energeticheskie kondensirovannye sistemy* [Energy condensed systems]. 3rd ed. Moscow: Yanus-K. 596 p.
24. Sympson, R. L., P. A. Urtiew, D. L. Ornellas, G. L. Moody, K. J. Scribner, and D. M. Hoffman. 1997. CL-20 performance exceeds that of HMX and its sensitivity is moderate. *Propell. Explos. Pyrot.* 22(5):249–255.
25. Pepekin, V. I., Yu. N. Matyushin, and T. V. Gubina. 2011. Enthalpy of formation and explosive properties of 5,6-(3,4-furazano)-1,2,3,4-tetrazine-1,3-dioxide. *Russ. J. Phys. Chem. B* 5(1):97–100. doi: 101134/S1990793111020102.
26. Mohammad, K., V. Thaltiri, N. Kommu, and A. A. Vargeese. 2020. Octanitropyrazolopyrazole: A gem-trinitromethylbased green high-density energetic oxidizer. *Chem. Commun.* 56:12945–12948. doi: 10.1039/D0CC05704E.
27. Zyuzin, I. N., I. Yu. Gudkova, and D. A. Lempert. 2022. Energy capabilities of some oxidizers with two N-trinitromethylazole fragments in one molecule as components of composite energy systems. *Russ. J. Phys. Chem. B* 16(5):902–911. doi: 10.1134/S1990793122060240.
28. Inozemtsev, Ya. O., A. V. Inozemtsev, M. N. Makhov, A. B. Vorobiev, and Yu. N. Matyushin. 2021. Calculation of detonation parameters of TKX-50 explosives. *Russ. J. Phys. Chem. B* 15(6):1005–1007. doi: 10.1134/S1990793121060178.

Received June 19, 2025
After revision August 14, 2025
Accepted August 25, 2025

Contributor

Makhov Michael N. (b. 1946) — Candidate of Science in chemistry, leading research scientist, N. N. Semenov Federal Research Center for Chemical Physics of the Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation; mmn13makhov@yandex.ru