Numerical simulation of formation and acceleration of high-density alloy fragments in a small-calibre short-range round

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The article presents results of numerical simulation and experimental studies of the explosion process of a fragmentation grenade from a small-calibre round for a promising automatic grenade launcher. We propose an improved design of a fragmentation shell for a 40 mm round that features annular controlled fragmentation regions made of a tungsten-based high-density alloy. We show that automated parametric meshing of components of a small-calibre round is possible. The study deals with the basic stages of forming and accelerating controlled fragments out of uniformly notched rings. We detected a range of triangle-shaped associated fragments generated via shear deformation in the notching sites. We provide static explosion test results for mockups of 40 mm fragmentation rounds featuring a set of rings manufactured by means of powder injection moulding. Statistical processing of mass and size characteristics in the fragment distribution obtained led to determining average acceleration velocity of the controlled fragments. We show that our numerical simulation converges with experimental data in terms of mass, geometrical and velocity characteristics of controlled fragments and their corresponding fragment distribution.

Keywords: *numerical simulation, small-calibre round, fragmentation shell, computational mesh, explosive acceleration, fragmentation, fragment distribution, fragments*

REFERENCES

[1] Babkin A.V., Veldanov V.A., Gryaznov E.F. et al. *Boepripasy* [Munitions]. In 2 vols. Vol. 1. Selivanov V.V., ed. Moscow, BMSTU Publ., 2016, 506 p.

[2] Zelenko V.K., Bryzzhev A.V., Zlobin V.V., Korolev V.M. *Pistoletnye i snayperskie patrony. Granatometnye vystrely* [Handgun and sniper rifle cartridges. Grenade launcher rounds]. Tula, Infra Publ., 2008, 120 p.

[3] Chizhevskiy O.T., Kosikhin A.I. *Arsenal Otechestva (Arsenal of the Fatherland)*, 2015, no. 2 (16). Available at: http://arsenal-otechestva.ru/article/445-pribor (accessed December 24th, 2017).

[4] *40-mm granatometnyy protivopekhotnyy kompleks 6G27 Balkan. AO NPO Pribor* [40 mm antipersonnel grenade launcher 6G27 Balkan. PJSC Scientific Production Association Pribor]. Available at: http://www.militarypribor.ru/ru/products/grl (accessed December 24th, 2017).

[5] Kobylkin I.F., Selivanov V.V. *Materialy i struktury legkoy bronezashchity* [Materials and structures of lightweight body armour]. Moscow, BMSTU Publ., 2014, 191 p.

[6] Zavora I.V., Kosikhin A.I., Nikolaev S.E., Chizhevskiy O.T. *Artilleriyskiy patron* [Artillery round]. Patent RU2421685, 2011, bulletin no. 17.

[7] Zavora I.V., Imkhovik N.A. Chislennoe modelirovanie osobennostey metaniya oskolochnoy obolochki, soderzhashchey gotovye porazhayushchie elementy iz tyazhelogo splava [Numerical simulation of acceleration specifics of a fragmentation shell featuring pre-formed high-density fragments]. *Trudy XXII Vse-*

rossiyskoy nauchno-tekhnicheskoy konferentsii Peredacha, priem, obrabotka i otobrazhenie informatsii o bystroprotekayushchikh protsessakh [Proc. of the 22nd Scientific and Technological conference Transmission, reception, processing and visualisation of data on high-speed processing]. Moscow, APR Advertising and Industrial Agency Publ., 2011, pp. 235–240.

[8] Zavora I.V., Imkhovik N.A., Solovev V.S. *Oboronnaya tekhnika — Defence technology*, 2011, no. 2-3, pp. 20–24.

[9] Imkhovik N.A., Zavora I.V. Chislennoe modelirovanie osobennostey vliyaniya svoystv VV i polozheniya tochki initsiirovaniya razryvnogo zaryada na protsess metaniya oskolochnoy obolochki, soderzhashchey blok GPE iz tyazhelogo splava [Numerical simulation of the specific ways that properties of the explosive material and the location of the point where the bursting charge is initiated affect acceleration of a shell comprising a pre-fragmented high-density alloy region]. *Sb. dokl. VII Nauchnoy konferentsii Volzhskogo regionalnogo tsentra, g. Sarov, 13 iyunya 2011 g. RARAN* [Proc. of the 7th Scientific Conference of the Volga Regional Center, Russian Academy of Missile and Artillery Sciences, Sarov, June 1st-3rd 2011]. Sarov, Russian Federal Nuclear Center — All-Russian Research Institute Of Experimental Physics Publ., 2011, pp. 430–436.

[10] Parkhomenko A.V., Amosov A.P., Samboruk A.R. *Naukoemkie tekhnologii v mashinostroenii — Science Intensive Technologies in Mechanical Engineering*, 2012, no. 12, pp. 8–13.

[11] Babkin A.V., Kolpakov V.I., Okhitin V.N, Selivanov V.V. *Prikladnaya mekhanika sploshnykh sred* [Applied continuum mechanics]. In 3 vols. Vol. 3: *Chislennye metody v zadachakh fiziki bystroprotekayushchikh protsessov* [Numerical methods in problems of physics of high-speed processes]. Selivanov V.V., ed. Moscow, Bauman Moscow State Technical University Publ., 2006, 520 p.

[12] Rusinek A., Zaera R. *International Journal of Impact Engineering*, 2007, vol. 34, no. 4, p. 799–822.

[13] *ANSYS Autodyn User's Manual*. ANSYS, Inc., Southpointe, 2013, 502 p.

[14] Lazarev Yu.F. *Modelirovanie protsessov i sistem v MATLAB* [Simulating processes and systems in MATLAB]. Saint Petersburg, Piter Publ., BHV Publ., 2005, 512 p.

[15] Winslow A.M. *Adaptive Mesh Zoning by the Equipotential Method*. UCID-19062. Livermore, Lawrence Livermore Nat. Lab., University of California, 1981.

[16] Hauver G.E. *The Hugoniot for 90W-7Ni-3Fe tungsten alloy: Report ARBRL-MR-02987*. U.S. Army Ballistic Research Laboratory, Maryland, 1980, 20 p.

[17] Andreev S.G., Babkin A.V., Baum F.A. et al. *Fizika vzryva* [Physics of Explosion]. In 2 vols. Vol. 2. Orlenko L.P., ed. 3rd ed., revised. Moscow, FIZMATLIT Publ., 2004, 656 p.

[18] Johnson G.R., Cook W.H. A constitutive model and data for metals subjected to large strains, high strain rates and high temperatures. *Proceedings of the 7th International Symposium on Ballistics*. The Hague, 19–21 April 1983, pp. 541–547.

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