Defence Science Journal, Vol. 68, No. 5, September 2018, pp. 445-450, DOI : 10.14429/dsj.68.12478

Small-Caliber Grenade Projectile Applicable to Individual Grenade Launchers

Michal Taraszewski* and Janusz Ewertowski

Department of Mechanics and Armament Technology, Warsaw University of Technology, Warszawa, Poland
**E-mail: Michal.Taraszewski@gmail.com*

ABSTRACT

An overview of development of grenade types for individual grenade launcher is presented. Considering historical and current research programs, a new type of projectile is proposed. Results of initial experiment which verifies chosen approach are included herein. It is said, based on obtained results, that showed new design can be applied in different applications without negative impact on combat capabilities – it even increases some crucial criteria. Current study indicates nearly 30 per cent increase of the effective exit velocity, however there is a design space where further investigation and optimisation can provide additional profits.

Keywords: 40 mm grenade; Light ogive; High-low propulsion system; Individual grenade launcher; NATO grenades

1. INTRODUCTION

Soldiers operating on the modern battlefield have at their disposal two main types of weaponry. These are an automatic rifle and an individual small-caliber grenade launcher. In the case of individual grenade launchers, their intensive development is observed in recent years. This applies to both the construction of the grenade launcher and the used ammunition.

The most spectacular example in this regard was the objective individual combat weapon (OICW[6]) program implemented by the US Army. As part of this program, a new, even revolutionary, concept of small-caliber grenade launcher was developed. First of all, it was distinguished by a reduced grenade caliber from 40 mm to 25 mm, which made it possible to increase the initial speed to over 200 m/s. As a result, the range of the shot increased by 2 to 2.5 times compared to the previous solutions. Such an increase can be determined only as an evident quality change in the development of individual grenade launchers. Secondly, a new type of ammunition was developed during this program. Ammunition equipped with programmable detonators ensuring detonation of the grenade at a fixed point of the track with unprecedented accuracy was proposed. Additionally, it was confirmed that the smaller caliber of grenades did not limit their ability to hit targets.

Moreover, in the case of grenade launchers, many types of ammunition are designed to effectively combat various targets. It is the possibility of using specialised ammunition that is the main advantage of grenade launchers defining their very high combat value. It is even said that the grenade launcher will soon become the main weapon of the modern soldier[11].

Authors reviewed and analysed existing designs and on this basis proposed a new type of grenade. The assumptions made on the basis of the experiment were verified, where the existing design was compared with a dummy grenade representing the new design.

Received : 15 January 2018, Revised : 12 July 2018
Accepted : 18 July 2018, Online published : 12 September 2018

2. OVERVIEW OF LOW CALIBER GRENADE AMMUNITION

2.1 40 mm x 46 mm Ammo

The development of modern, small-caliber grenade launcher began with the introduction of the M79 grenade launcher in 1961 on the US Army. For this weapon, ammunition of a new type has been developed, distinguished by the use of a two-chamber propelling system (a.k.a. High-Low System or High-Low Propulsion System). This solution made it possible to obtain a stable combustion process of the propelling charge. The propellant charge is placed in a high pressure chamber with a relatively small volume, from which, at the moment of firing the shot, the propellant gases enter the low pressure chamber, propelling the projectile-grenade. Thanks to this, in the low pressure chamber, the gas pressure is significantly lower, which in turn provides the recoil energy of the entire weapon at a level that does not endanger the user.

The bullet-grenade itself (marked M 381) has a steel, spherical insert with an high explosive (HE) inside. This insert is built into the aluminum body of a projectile. The aluminum body on its outer surface has guide rings that allow the grenade to be fired from the threaded barrel. The head igniter is placed under the ballistic cap. The hull is made of duralumin which at the time was an unparalleled solution.

2.2 40x47 mm Ammo

In the review of small-caliber grenade ammunition, it is worth paying attention to the Polish construction of the cartridge (NGO-74[5]) intended for the Pallad-D[4] – an underslung (under-barrel) grenade launcher. The cartridge grenade is made in a fragmentation version. As in the previously described case, a two-chamber propelling system was used. The pressure prevailing in the low pressure chamber is about 21 MPa, while in the high pressure chamber it is at least 5-6 times higher. In the grenade, in the rear part of the body, a cast steel insert is embedded, inside which the detonating material is placed. As the detonating material, hexogen phlegmatised with aluminum powder was used. Detonation of the projectile occurs after hitting any surface with an obstacle, not necessarily the frontal surface. The front part of the body closes with a duralumin ballistic cap. A GZB-74 igniter is installed under the ballistic cap (ogive).

In the many years of use of this cartridge, various versions have been developed, such as fragmentation, ballistic, training and testing.

2.3 WOG-25 Ammo

In the case of the ammunition discussed above, in each case they were constructions using a typical two-chamber propelling system. The same issue of throwing grenades has been differently solved in Russian constructions.

In 1974, the VOG-25 grenade was introduced to the armaments of the Soviet Army. Five years later he was joined by a ‘bouncing’ grenade VOG-25P. These were cartridges designed for a GP-25 grenade launcher suspended under AKM and AKMS rifles.

The grenades used in this ammunition stood out from the other constructions with the original solution of the propelling system. It was characterised by the fact that the cylindrical high-pressure chamber was permanently attached to the back of the grenade body and was fired with it from the barrel. In such an arrangement, there is no low-pressure chamber in the initial phase of the shot. It is formed only when the grenade begins to move along the barrel. This solution eliminated the need for a hull, which should be considered as the development of a type of non-hulled ammunition.

In the grenades head and impact warheads of immediate action were used. They are equipped with distance arming, depending on the temperature of 10-40 m from the barrel outlet, and self-timer operating after 14-19 seconds from the moment of arming the projectile. In the ‘bouncing’ VOG-25P grenade there is a ballistic charge placed in fuse, which explodes after hitting an obstacle or ground. It ejects the shell upwards, even to a height of 1.5 m, and only then does the detonation of the main load take place. As a result, it was possible to increase by more than 1.5 times effective damage area of targets on the ground and up to 2 times targets in entrenchments. The main source of fragments is the grenade body.

This solution has a number of advantages. The weight of the shellless cartridges is smaller than the standard ammunition, and what is also important, the rate of fire increases to 4-5 rounds / min with aiming and manual reloading. This is possible because it is not necessary to remove the hull from the chamber every time, and the grenade launcher can be operated with one hand.

Of course, the lack of the hulls complicates the construction of the grenade launcher due to the problem of sealing the back of the barrel. In this case, it was solved by loading the grenade launcher from the front of the barrel, which may raise doubts and safety concerns.

2.4 25 mm x 59 mm Ammo Family

The latest solutions of small-caliber ammunition grenades are American constructions developed within the framework of the OICW program[6] (concerning the armament of a future soldier) for the 25 mm grenade launchers mentioned at the beginning. The developed cartridges present a new concept of a solution in which the propelling system is much closer to classic rifle cartridges. For the first time, a two-chamber propelling system was not used here.

It can be assumed that reducing the caliber to 25 mm allowed for a stable combustion process of the propelling charge. As a result, it enabled the elimination of the twin-chamber propelling system, simplifying the hull production. In the previous ammunition, its serious disadvantage, increasing production cost, was the intricate internal shape of the hull housing two high and low pressure chambers.

The grenade itself is a highly technically advanced construction. First of all, the use of a programmable fuse coupled with a fire control system placed on a grenade launcher should be mentioned. Using this set, the soldier has the ability to measure the distance from the target using a laser range finder, and then can program the fuse to determine the distance at which the detonation is to take place. Distance programming allows you to determine the location of the detonation both before and after the target. Usually detonation takes place in the air while the projectile is flying on the ballistic track. It is not required, as in hitherto solutions, to hit the target. Also new is the use of two detonating warheads, one of which is placed in the front and the other in the rear of the projectile. It also increases the effectiveness of target destruction.

Such a solution of a projectile-grenade, as it is initially assessed, increased the effectiveness of target destruction five times. However, it is a drawback that due to the use of advanced technical solutions used in this ammunition, its cost according to the manufacturer is 10 times higher than in standard grenades with impact fuses.

3. PROPOSED LOW-CALIBER GRENADE LAUNCHER AMMUNITION

Analysing the presented construction solutions of modern, small-caliber grenade ammunition, two basic conclusions can be formulated, i.e.:

1. The 40 mm NATO barrel standard for individual grenade launchers is not the only one possible and, what is more important, it may not be optimal in terms of effective target damage. This is confirmed by the 30 mm caliber ammunition in the Russian Army (not shown in this paper), as well as the work in the United States on future grenade launchers in which 25 mm caliber is expected.
2. Adoption of the 40 mm caliber as a standard limits the maximum initial velocity of the launched projectile to 80 m/s. It is caused by maximum acceptable recoil force which can be safely absorbed by a shooter. Consequently however, this results in the size of the useful range of the shot possible to achieve. It closes within 400 m. At the

same time the consequence of the low initial speed is the relatively large spread of this speed when the projectile exits the barrel. This, in turn, clearly reduces the accuracy of the shot, which is known and confirmed practically in the use of this weapon. In addition, getting a larger range requires firing using high angles to raise the barrel. This also has negative effects on the accuracy of the weapon.

Bearing in mind the mentioned above, it can be concluded that the imposition as a standard of 40 mm caliber is a significant limitation of the development possibilities of ammunition and small caliber, individual grenade launchers.

The authors of this article, within the framework of their own research and development works, undertook the task of increasing functional and combat capabilities of the ammunition for individual small-caliber grenade launchers, assuming the maintenance of a standard 40 mm caliber. Such an action is primarily justified by economic reasons.

First of all, the work concentrated on searching for new concepts of the projectile's design solution. Without describing the individual stages of the implementation of the adopted task, in the end, a new type of projectile-grenade cooperating with the previously used two-chamber shell was developed.

The essence of the solution is to put a grenade, with a caliber less than 40 mm, inside a thick-walled ogive adjusting the projectile to the standard 40 mm caliber required. Both elements are connected in a permanent way creating together a single projectile shot from a grenade launcher. The outer shell does not separate when the projectile exits the barrel, which is dictated by the safety of persons in the vicinity of the shooter. The use of such a solution ensures reduction of the total weight of the projectile, as a result of which it becomes possible to increase its initial velocity without increasing the energy of recoil of the whole weapon. The latter was a key requirement: achieve improvement of the effective exit velocity without increasing the recoil force. Higher recoil force might arise soldiers safety concerns.

As a result, the previously discussed 40 mm ammunition defects will be significantly reduced or even eliminated. The most valuable, however, will be the possibility of increasing the range of the shot, which will directly affect the increase in the combat value of the currently used grenade launcher. Example design of new type ammo is as shown in the Fig. 1.

As can be seen from the figure above, the use of thick-walled ogive (1) provides great freedom in the construction

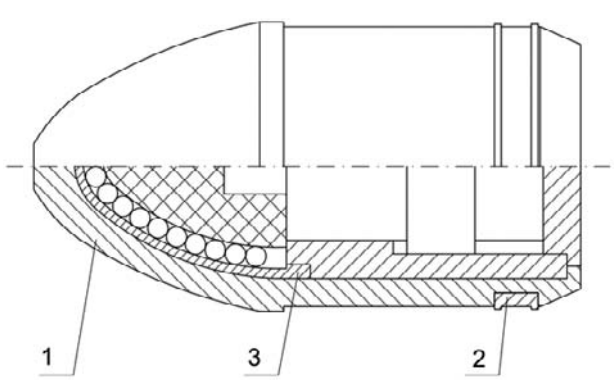

Figure 1. Half section of the low-caliber grenade projectile.

of battle grenade both in terms of caliber and longitudinal linear dimensions. The thick-walled ogive also has a leading ring (2), which can be an integral part of the ogive as well as embedded in it. The entire projectile is closed from the front with a ballistic cap/ogive (3). Further details can be found in patent number P.421581[3].

Assessing the proposed projectile as a valuable solution against existing models of small-caliber grenade ammunition, it was decided to conduct a short, preliminary experimental study of several model pieces. For this purpose, a design of the experimental projectile was made, in which the distribution and size of individual masses were determined using computational methods[1,2,9,10] so that the conditions of flight stabilisation were met[1,7]. The projected projectile was made in the prototype plant of the Department of Mechanics and Armament Technology at Warsaw University of Technology (WUT), and then integrated with typical two-chamber cartridge case of currently used NGO-74 ammo. Usage of NGO-74 cartridge case is driven by requirement of keeping same level of the recoil energy, which was mentioned earlier. Other cartridge cases with different propellants are not considered in this paper – the purpose is to perform a back-to-back analysis of new versus old design. Comparison between dummy grenade and ammunition used in Pallad-D grenade launcher is as shown in the Fig. 2.

Machined in the prototype plant projectiles have had experimental usage only – to verify technical parameters. They do not represent an initial production version. Design intent was to run laboratory tests and formulate conclusions about proposed approach.

4. EXPERIMENT AND METHODOLOGY

Experiment was conducted in the Warsaw University of Technology (WUT) armament laboratory. Test set-up is presented in Fig. 3. Test bed fixture (1) is a heavy weight steel

(a) (b)

Figure 2. Grenade-projectile: (a) NGO-74 40x47, (b) dummy type of new ammo.

table grounded to the lab floor. 40 mm threaded barrel (3) is restrained via mounting feature (6) which is connected to the test bed fixture. Grenade (2) is put in barrel chamber from the aft side when receiver (5) is taken down. Once ammo reaches its desired place, receiver is tighten back. During each shot, static pressure and projectile speed data is acquired. Pressure is measured by Kistler 7055A1 piezoelectric sensor (4) and then send to PC unit, whereas projectile speed is measured by custom made speed gates (7) with integrated display screen.

Two types of grenades were tested. The first one represents the type of training of the NGO-74 40x47 grenade for Pallad-D light grenade launcher, the second is a dummy representation of a new type of projectile – it must reflect mass only. Both are as shown in the Fig. 2. In order to perform comparative analysis it was decided to use same cartridge case with a propellant charge and a primer for both ammunition tested. The propellant set-up comes from the original NGO-74 40x47 combat grenade which allows to do back-to-back analysis of new versus old design. Relative change of projectile effective exit velocity was a major interest.

Test stand equipment:

- 4x training type of NGO-74 40x47 grenade
- 3x dummy version of new type grenade
- Piezoelectric pressure sensor, type: 7055A1(a Kistler company)
- Charge amplifier x1 (a Kistler company)
- Digital recorder – custom made recorder dedicated for WUT ballistic lab;
- Custom made speed gates with integrated display screen.

Test was conducted with shot by shot regime, with time to cool barrel down. After each shot barrel was cleaned.

5. RESULTS AND DISCUSSION

There were four shots with training type NGO-74 40x47 with an average mass of 190 g. Three other shots were shot with a new type of projectile with an average mass of 140 g. The pressure levels for both types of grenades are similar (Fig. 4), which can be stated that the entire propellant charge during the acceleration phase of the new grenade has been burnt. The effective projectile velocity of the projectile increased by 29 per cent from 72 to 93 m/s, which is a significant improvement. Comparing the standard deviation for pressures and speeds between the two types of grenades studied, it can be concluded that the new type of ammunition has better precision of this old type. Various types of filtration data were used: digital[8] and analogue, with 4.7 kHz cutoff frequency. Details can be found in Table 1.

Table 2 indicates t-Student coefficients which are used to calculate velocity variation. Three confidence coefficients were used: 0.9, 0.95, 0.99, and two degrees of freedom: 2, 3.

Table 2. t-Student coefficients

n-1↓ / 1-α→	0,9	0,95	0,99
2	2,92	4,3027	9,9248
3	2,3534	3,1824	5,8409

where n – sample count, α – statistical significance

In Table 3 calculated velocity variations are presented. In example, for new grenade, 2 degrees of freedom and 90 per cent of confidence level, velocity variation is equal to 3.46 m/s. It means that best estimation of velocity is 93.07 m/s with 3.46 m/s uncertainty. Hence one can say that with 90 per

Table 1. Results details

Grenade	Mass (g)	Average mass (g)	Filter type	Filter freq. (kHz)	Pressure (MPa)	Average pressure (MPa)	Pressure SD (MPa)	Velocity (m/s)	Average velocity (m/s)	Velocity SD (m/s)
NGO-74 40x47	190,05	190,08	Digital	4,7	11,884	11,22	1,20	69,30	72,14	3,83
NGO-74 40x47	190,17		Digital	4,7	10,281			68,44		
NGO-74 40x47	190,08		Analogue	4,7	12,573			76,14		
NGO-74 40x47	190,01		Analogue	4,7	10,144			74,66		
New	137,56	139,69	Analogue	4,7	no data*	10,52	0,28	92,64	93,07	1,19
New	140,46		Analogue	4,7	10,718			92,16		
New	141,04		Analogue	4,7	10,327			94,41		

* - pressure not registered (pressure sensor was not excited), other parameters acquired.

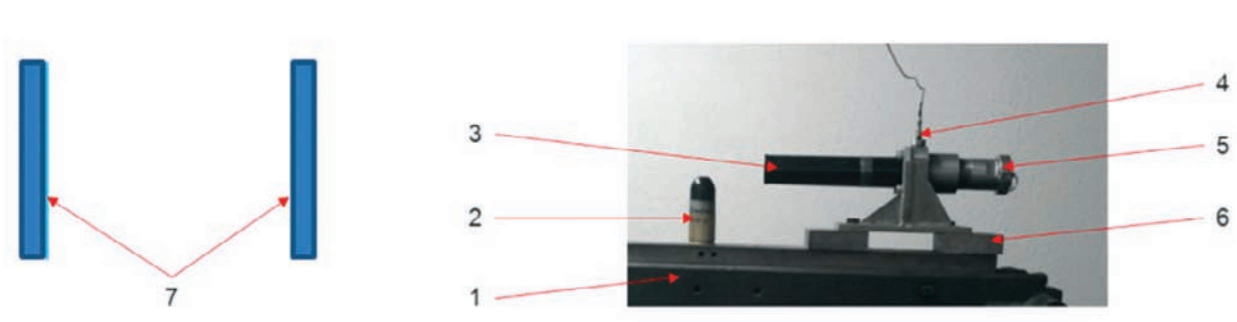

Figure 3. Experiment set-up– overview: 1- test bed fixture, 2- grenade, 3- threaded barrel, 4- piezoelectric pressure sensor, 5- receiver, 6- mounting feature, and 7- speed gates.

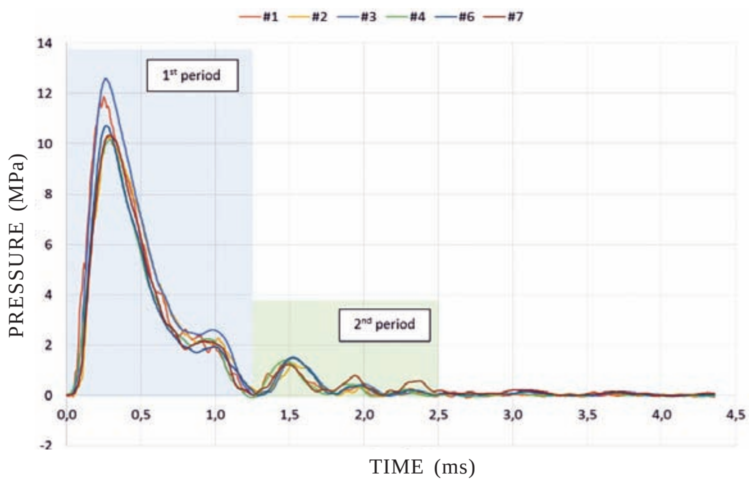

Figure 4. Pressure characteristics for existing (#1-4) and new (#6-7) type of grenades.

cent of confidence (or 10 per cent uncertainty) velocity of new grenade type is 93.07 ± 3.46 m/s. Similar approach is valid for other cases. This analysis shows that new projectile has lower error in terms of velocity variation.

Table 3. Velocity variation

Grenade type	n-1	$t^{\alpha}_{n-1} \cdot SD$		
		1-α = 0.90	1-α = 0.95	1-α = 0.99
New	2	3.46	5.10	11.76
NGO-74 40x47	3	9.02	12.20	22.40

In the Fig. 4 pressure characteristics are shown for all tested cases – numbering according to the Table 1. What can be observed is that received results from experiment are repetitive in terms of characteristic and magnitude for both type of grenade. Maximum pressure peak is observed for 0.25 (ms). Two ranges can be observed. First, major pressure period which accelerates projectile lasts from 0 till 1.25 (ms), while second portion is that what has been reflected from back end of the moving in the barrel projectile – that period lasts from 1.25 until 2.5 (ms). Average pressure impulse for 1st period is 5.17 (MPa· ms), and for 2nd period 0.47 (MPa· ms).

It may be concluded that propellant set-up from the original NGO-74 40x47 combat grenade can be used for new type with same efficiency. Experimental data can also be useful when designing a new type of grenade launcher – it shows how much impact energy is stored in the original NGO-74 40x47 propellant.

6. CONCLUSIONS

It may be stated that this paper and proposed approach introduce a new look into back-to-back analysis of grenade ammunition. Research experiments were carried out to assess the rationale of existence of the new projectile type based on existing propellant set-up. The levels of speed and pressure pulse were compared. The comparison showed that the new design introduces a significant improvement in the effective projectile velocity, while the pressure characteristics and magnitudes are similar and repeatable. Hence the conclusion that the entire propellant charge in the acceleration phase of the new type was burned – as in the base NGO-74 40x47 grenade. It is also worth emphasising that the improvement of the effective exit speed has met the requirement of a similar level of recoil energy to the original solution. A similar comparison can be made for other types of grenades and one might also expect significant improvement in their combat parameters. Further research in the field of aerodynamic shape, mass, propellant can be carried out in order to obtain an even better shape of the projectile. Finally, it can be concluded that the initial research and development work confirmed the possibilities of optimising the design in terms of mass, and thus increase the combat parameters of the grenade.

REFERENCES

1. Carlucci, D.E. & Jacobson, S.S. Ballistics: Theory and design of guns and ammunition, Second Edition. CRC Press., 2013.
2. Engineering Design Handbook - Elements of armament engineering, Part Two - Ballistics, U.S. Army Materiel Command, AMCP 706-107
3. Ewertowski, J. & Taraszewski, M. Small-caliber grenade projectile applicable to individual grenade launchers. Polish Patent P.421581, 2017.
4. Gwóźdź, Z. Pallad. Commandos, Military Magazine, 1997, **5**, 65 – 67.
5. Gwóźdź, Z. 40mm x47. Commandos, Military Magazine,1997, **5**, 67 – 68.
6. Mazeski, R. & Steimke, D. XM307 Program reliability growth, ammunition development and advanced technology demonstration tests. *In* Proceedings of the Small Arms Symposium & Exhibition, National Defense Industrial Association, Kansas City, MO, 2003.
7. McCoy, R.L. Modern Exterior Ballistics: The launch and flight dynamics of symmetric projectiles. Schiffer Publishing, Ltd, 2012.
8. O'Haver, T. Interactive signal processing tools. Website: https://terpconnect.umd.edu/~toh/spectrum/SignalProcessingTools.html, (Accessed on 10 November 2017).
9. Peter, H. Armament engineering: A computer aided approach. Trafford Publishing, 2005.
10. Peter, H. Mechanical engineering: Principles of armament design. Trafford Publishing, 2005.
11. Salwan, S.K. Conventional armaments for coming decades. *Def. Sci. J.*, 1997, **47**(4), 417-426. doi: 10.14429/dsj.47.4026

ACKNOWLEDGMENTS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CONTRIBUTORS

Mr Michał Taraszewski received his MSc in 2013 and currently pursuing PhD in the field of weapon accuracy at the Department

of Mechanics and Armament Technology at Warsaw University of Technology (WUT). His research areas include: Mathematical modelling of shooter-weapon interaction, work on new type of grenade launcher and its ammunition.
His contribution to the current study include: Preparation and conduct of the experiment, results validation and post-processing, carry out numerical analysis.

Prof. (Dr) Janusz Ewertowski received his MSc and PhD at the Department of Mechanics and Armament Technology at Warsaw University of Technology (WUT). He was several times head of the Department and head of the Institute of Mechanics and Construction at Warsaw University of Technology. He is currently serving as a Professor. His research areas include: shooter-weapon interaction, work on new type of weapons, new types of ammunition, optimisation current designs, autonomous vehicles.
His contribution to the current study include: review and analysis of existing designs, preliminary analysis of the new grenade, mentoring