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Preliminary Comparative Investigations on Ballistic Properties of Intermediate Cartridges

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Abstract. The preliminary results of comparative investigations on intermediate cartridges were presented in this paper. The research focused mainly on the adopted assumptions and verification of research methods. Pressure ballistic test barrels, manufactured according to NATO EPVAT standards, were used for tests. The pressure courses of propellant gases in the barrel and the projectile velocity at four points of the bullet trajectory were measured. The pressure impulses, R_{100} parameter at 50 m and average bullet drag coefficient were calculated for each type of cartridge. The results allowed for a preliminary ballistic comparison of the most popular types of intermediate cartridges.

Keywords: interior ballistics, external ballistics, ballistic properties, small arms ammunition

NOMENCLATURE

C_d	bullet drag coefficient
L	barrel length
L_1, L_2	positions of pressure measurement points in relation to the barrel inlet
m_p	bullet mass
P_1, P_2	pressure measured at the positions L_1 and L_2, respectively
PI_1, PI_2	pressure impulse calculated for P_1 and P_2 courses, respectively
S_p	bullet cross-section area
t	time
t_{25}, t_{50}	time of reaching the distance of 25 meters and 50 meters
v_p	bullet velocity in 1D motion model
V_M	bullet muzzle velocity
V_2, V_{25}, V_{50}	experimentally obtained bullet velocities at 2, 25, and 50 meters
ΔV_{50}	bullet velocity drop at 50 meters (V_M - V_{50})
x_p	bullet coordinate (distance) in 1D motion model
X, Y	bullet coordinates at 50 meters
ρ_a	air density

1. INTRODUCTION

Until the World War II, bolt action rifle was a soldier's basic individual weapon [1]. The range of ammunition used in such a firearm significantly exceeded the ability of detected targets with mechanical sights. From a practical point of view, this resulted in a senseless waste of gunpowder and materials, which were scarce in wartime conditions. What is more, a rifle cartridge is characterized by large size and weight, which significantly limited the amount of ammunition which single soldier could take. The high energy of rifle rounds was the cause of the weapon considerable size, weight and was characterized by high recoil, which reduced the practical rate of fire.

The World War II has become a renaissance of firearms using ammunition with a much lower energy level. Submachine guns were light, had a simple design and high rate of fire. A pistol cartridge was much lighter and smaller than a rifle cartridge, therefore it ensures the higher transport ability of the soldier. However, the main disadvantage of the submachine guns was an effective range of 100-200 m. Due to this fact, submachine guns had to be used simultaneously with bolt action rifles.

Intermediate cartridges were developed as a compromise between rifle and pistol cartridges. Due to the energy of the bullet, it was placed in the middle of these two types of cartridges. An effective range has been reduced to a realistic level for mechanical sights.

Such ammunition is characterized by the smaller and lighter cartridges, a higher rate of fire and lower material consumption compared to rifle ammunition. At the same time, it eliminated the biggest disadvantage of pistol ammunition – an effective range.

The time after the World War II was a period of rapid development and the domination of intermediate cartridges for small arms. The historical division of the world into two camps was also reflected in ammunition. The basic ammunition of the former Eastern Block countries – 7.62x39 mm and its successor 5.45x39 mm was developed in the USSR. Most Western Block countries use 5.56x45 mm cartridges (SS109, M193).

Development of the .300 ACC Blackout (.300 BLK) ammunition by the US Company Advanced Armament (ACC) was intended to provide the performance of 7.62x39 mm cartridge in a configuration for the adapter AR-15 assault rifles [2]. This ammunition uses the standard 5.56x45 mm magazines with no capacity loss. As reported .300 BLK 8.1 g bullet is characterized by 16% higher muzzle energy than the 5.56x45 mm (SS109). In Fig. 1, different types of intermediate rounds were shown.

The paper presents preliminary results of the research aimed at verification of the correctness of the adopted assumptions and research methods.

Fig. 1. Intermediate cartridges. From left: .300 ACC Blackout plastic tipped, .300 AAC Blackout 125 gr, .300 ACC Blackout 220 gr subsonic, 5.56x45 mm NATO, 7.62x39 mm (wikipedia.org)

2. EXPERIMENTAL STAND AND METHODS

Four types of cartridges were tested:

1. 5.56x45 mm Pb (lead core) – bullet weight: 3.54 g, manufacturer: MESKO S.A.

2. 5.56x45 mm RS (steel core) – bullet weight: 4 g, manufacturer: MESKO S.A.
3. 7.62x39 mm PS (steel core) – bullet weight: 7.9 g, manufacturer: MESKO S.A.
4. .300 Blackout HP 125 gr – bullet weight: 8.1 g, manufacturer: Hornady.

For each type of cartridges, seven tests (shots) were carried out. The Prototypa mobile firing rest STZA12M1 with universal ballistic breech UZ-2002 and pressure ballistic test barrels manufactured according to NATO EPVAT standards were used to tests [3]. Several parameters were measured:

- propellant gas pressure in a barrel – Kistler piezoelectric pressure sensors type 6215. Except for the 7.62x39 mm PS, where the barrel made in the NATO EPVAT standard has only one measurement (gauge) point, two values of pressure were recorded in each case. The positions of the gauge points in relation to the barrel inlet are summarized in tables 1-4;
- bullet muzzle velocity – Prototypa muzzle velocity head EMG-1;
- bullet velocity at 2 m – Prototypa intelligent light gate LS-01L;
- bullet velocity at 25 m – Kistler light screen type 2521A;
- bullet velocity and coordinates at 50 m – Kistler target system type 2523A.
- Kistler transient recorder for ballistic applications type 2519A were used for data acquisition and postprocessing.

Moreover, assuming the flat trajectory of the projectile, the average value of a drag coefficient for each projectile was estimated. A set of equations describing projectile motion can be written as:

$$\frac{dv_p}{dt} = -\frac{C_d S_p \rho_a v_p^2}{2m_p}, \tag{1}$$

$$\frac{dx_p}{dt} = v_p. \tag{2}$$

Assuming the initial conditions for the under-investigation problem in the following form:

$$v_p(t = 0) = v_2 , \tag{3}$$

$$x_p(t = 0) = 2 . \tag{4}$$

it is possible to estimate the projectile average drag coefficient by approximation of experimentally obtained data. The iterative algorithm used the 4th order Runge-Kutta numerical scheme to solve the set of equations (1) and (2). In the presented approach, the minimization of a quadratic error sum was required:

$$\min\left[\left(V_{25} - v_p(t_{25})\right)^2 + \left(V_{50} - v_p(t_{50})\right)^2\right] \tag{5}$$

In the above-presented approach, the bullet characteristic dimensions were obtained from the literature [4].

As it can be seen, the intermediate ballistics region was omitted in calculations. Exemplary results of approximation were presented in Fig. 2.

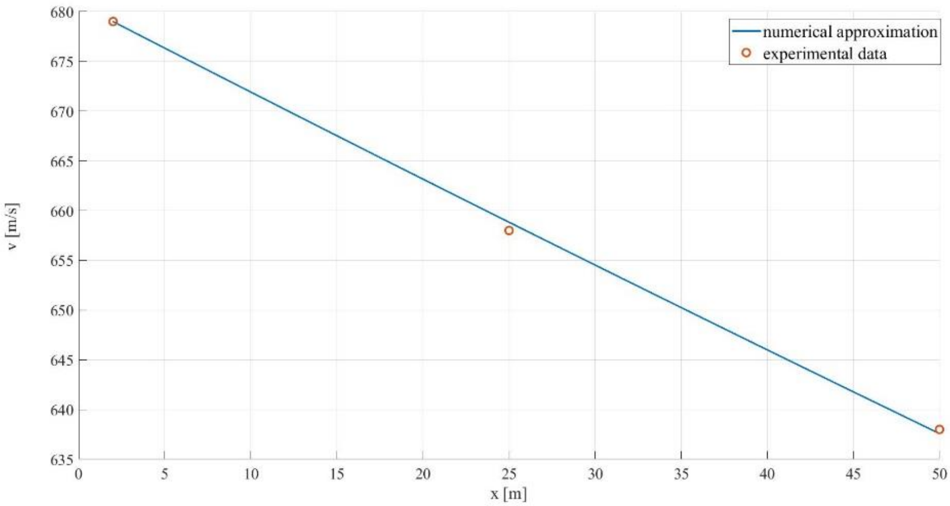

Fig. 2. Exemplary results of numerical approximation of a projectile velocity

3. RESULTS

3.1. 5.56x45 mm Pb

At first, the very popular in civil application, 5.56x45 mm bullet with lead core was investigated. The results shown in Tab. 1 and 2, as well as in Fig. 3 and 4 provide very low dispersion of the measured parameters for interior ballistic properties and the estimated drag coefficient. The target dispersion parameters obtained during the tests are much less satisfactory.

As it can be noticed in Fig. 3, the gas pressure was measured outside of the case – rapid jump of the pressure value corresponds with the opening of the gauge orifice. What is important, in case of intermediate ammunition, in contrast to pistol ammunition [5], the maximum pressure point is obtained after the bullet leaves the case what eliminates the necessity of case drilling to measure the maximum gas pressure.

In Figure 5, the comparison of average pressure courses for two gauge points were presented. These results aimed to show the time interval between pressure jumps, recorded by transducers, which can be useful in validation of interior ballistics numerical models. The average value of this interval was equal to 0.5 ms.

Table 1. Summary of 5.56x45 mm Pb cartridge

No.	P_1 [MPa]	PI_1 [MPa*ms]	P_2 [MPa]	PI_2 [MPa*ms]	V_M [m/s]	V_2 [m/s]	V_{25} [m/s]	V_{50} [m/s]	ΔV_{50} [m/s]	X [mm]	Y [mm]
1	316.6	191.7	110.5	66.3	971.2	975.4	944.9	915.5	55.7	-62.0	-12.5
2	315.2	184.9	110.7	66.3	974.7	978.1	946.9	917.6	57.1	-54.5	-21.7
3	316.1	189.7	110.2	66.7	972.8	973.0	943.0	914.3	58.5	-25.7	-33.1
4	313.0	191.4	111.1	67.3	970.9	972.6	940.7	911.2	59.7	-59.7	-38.2
5	309.7	195.7	111.3	67.8	962.5	962.5	933.6	903.9	58.6	-69.4	-34.7
6	319.2	194.7	110.1	66.9	972.8	973.3	942.4	913.2	59.6	-28.0	-23.9
7	322.5	195.0	110.0	67.0	973.7	977.1	946.0	917.1	56.6	-61.9	-35.6
min	309.7	184.9	110.0	66.3	962.5	962.5	933.6	903.9	55.7	-69.4	-38.2
max	322.5	195.7	111.3	67.8	974.7	978.1	946.9	917.6	59.7	-25.7	-12.5
Δ	12.8	10.8	1.3	1.5	12.2	15.6	13.3	13.7	4.0	43.7	25.7
Average	316.0	191.9	110.6	66.9	971.2	973.1	942.5	913.3	58.0	-51.6	-28.5

Standard / Type: EPVAT pressure; L=508.0 mm, L_1=46.5 mm, L_2=280.0 mm

Table 2. Estimated drag coefficient of 5.56x45 mm Pb cartridge

No.	Mach number range [-]	Average Mach number [-]	Average drag coefficient [-]
1	2.69 ÷ 2.87	2.78	0.303
2	2.70 ÷ 2.88	2.79	0.309
3	2.69 ÷ 2.86	2.78	0.304
4	2.68 ÷ 2.86	2.77	0.321
5	2.66 ÷ 2.83	2.75	0.305
6	2.69 ÷ 2.86	2.77	0.310
7	2.70 ÷ 2.87	2.79	0.309
Average		**2.78**	**0.309**

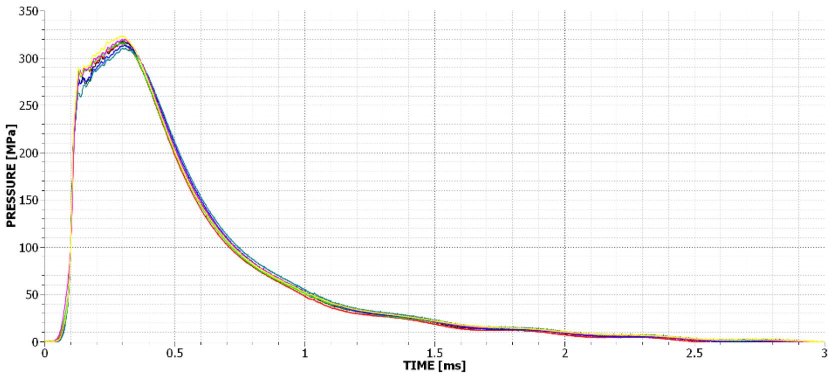

Fig. 3. The courses of pressure measured at L_1=46.5 mm from a barrel inlet for 5.56x45 mm Pb

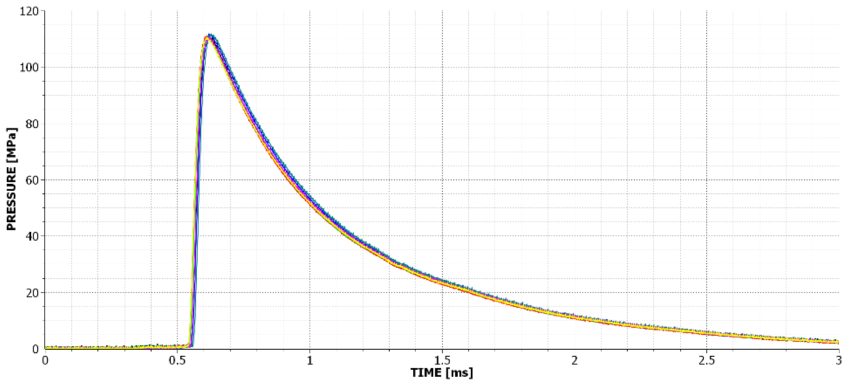

Fig. 4. The courses of pressure measured at L_2=280 mm from barrel inlet for 5.56x45 mm Pb

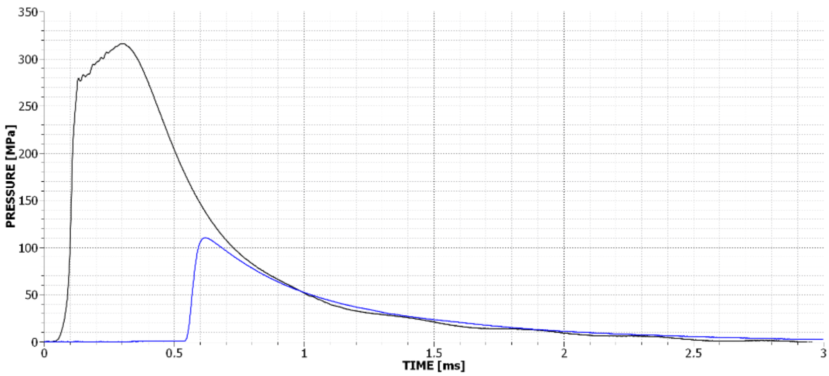

Fig. 5. Average courses of pressure measured for 5.56x45 mm Pb

3.2. 5.56x45 mm RS (steel core)

Next investigated type of a bullet in case of 5.56x45 mm was the steel core projectile. As presented in Tab. 3, Fig. 6, and Fig. 7, similarly to the previously investigated bullet, the interior ballistics parameters are characterized by low dispersion. Unfortunately, the impact points dispersion at the distance of 50 m are much poorer and it can be particularly noticed in the Δ value for *Y* coordinate, which is almost twice larger than for the Pb bullet.

The results of a drag coefficient numerical approximation were summarized in Tab. 4 and seem to be very interesting. Construction of the investigated bullet can be comparable with M855 projectile and the values of a drag coefficient are close to these presented in [6] for M855. Moreover, taking into account the shapes of noses for two studied projectiles, it was expected that Pb bullet was characterized by the higher value of a drag coefficient, which was confirmed by a numerical approximation of this parameter.

The average value of the estimated coefficient was approx. 9% larger for Pb bullet than for the RS (steel core) one. It should be also noticed that for the same value of the Mach number, the expected discrepancy should be larger.

Due to similar interior ballistic parameters of two 5.56 mm bullets, the values of a pressure jump delay are also close, which can be observed in the pressure courses comparison shown in Fig. 8.

Table 3. Summary of 5.56x45 mm RS cartridge

No.	P_1	PI_1	P_2	PI_2	V_M	V_2	V_{25}	V_{50}	ΔV_{50}	X	Y
	[MPa]	[MPa*ms]	[MPa]	[MPa*ms]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[mm]	[mm]
1	327.6	202.4	113.4	69.4	932.8	930.9	907.9	885.8	47.0	-32.5	-42.0
2	338.4	200.0	111.9	66.5	927.6	933.4	908.2	885.6	42.0	-73.0	-9.6
3	332.3	207.1	112.3	68.8	928.5	930.4	905.9	883.5	45.0	-60.0	-45.7
4	343.7	211.2	114.6	69.5	932.0	933.5	909.8	887.6	44.4	-26.5	-23.4
5	345.0	211.2	113.5	67.5	934.6	936.7	912.8	890.1	44.5	-43.4	-29.8
6	346.4	206.5	112.8	66.4	940.7	943.2	919.5	897.3	43.4	-52.9	-36.8
7	351.0	203.2	113.0	65.1	941.6	942.7	916.4	891.5	50.1	-71.6	-56.0
min	327.6	200.0	111.9	65.1	927.6	930.4	905.9	883.5	42.0	-73.0	-56.0
max	351.0	211.2	114.6	69.5	941.6	943.2	919.5	897.3	50.1	-26.5	-9.6
Δ	23.4	11.2	2.7	4.4	14.0	12.8	13.6	13.8	8.1	46.5	46.4
average	340.6	205.9	113.1	67.6	934.0	935.8	911.5	888.8	45.2	-51.4	-34.8

Standard / Type EPVAT pressure, L=508.0 mm, L_1=46.5 mm, L_2=280.0 mm

Table 4. Estimated drag coefficient of 5.56x45 mm RS cartridge

No.	Mach number range [-]	Average Mach number [-]	Average drag coefficient [-]
1	2.61 ÷ 2.74	2.67	0.273
2	2.61 ÷ 2.74	2.67	0.287
3	2.60 ÷ 2.74	2.67	0.280
4	2.61 ÷ 2.74	2.68	0.279
5	2.62 ÷ 2.76	2.69	0.283
6	2.64 ÷ 2.77	2.71	0.274
7	2.62 ÷ 2.77	2.70	0.308
average		**2.68**	**0.283**

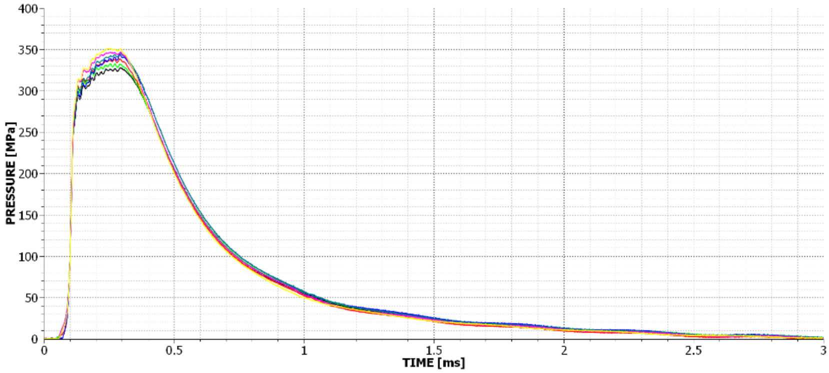

Fig. 6. Courses of pressure measured at L_1=46.5 mm from a barrel inlet for 5.56x45 mm RS

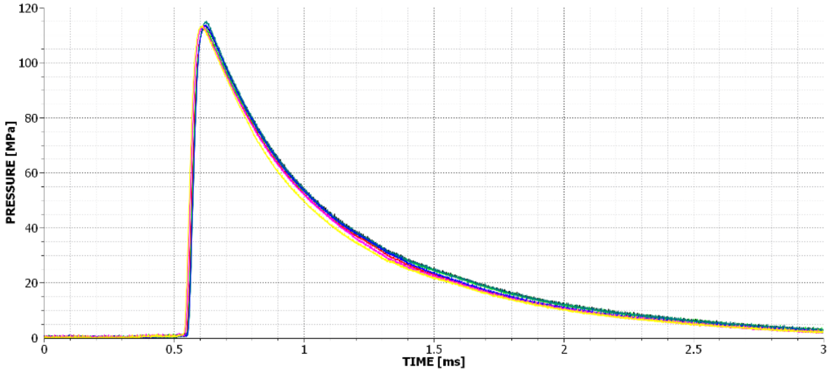

Fig. 7. Courses of pressure measured at L_2=280 mm from a barrel inlet for 5.56x45 mm RS

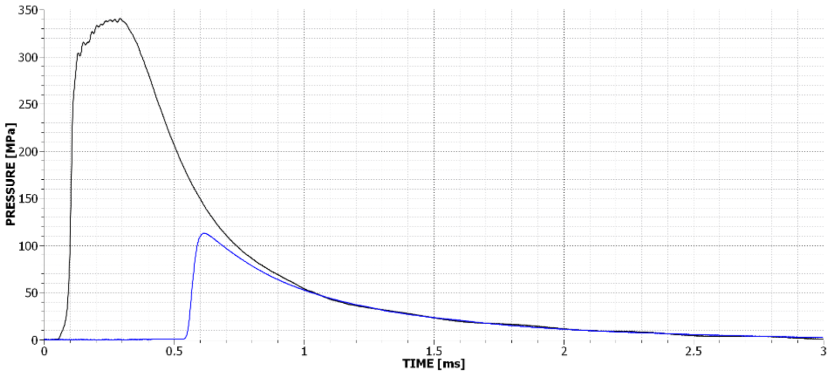

Fig. 8. Average courses of pressure measured for 5.56x45 mm RS

3.3. 7.62x39 mm PS (steel core)

Further measurements were conducted for 7.62x39 mm round equipped with a steel core bullet. In this situation, due to the barrel standard, only one gauge was applied. In this case, the direct comparison with 5.56x45 mm seems to be senseless, due to absolutely different construction, i.e., drastically different geometrical and inertial properties. Despite this fact, due to possible application of conversion systems, we have compared these types of ammunition. As it can be observed (Tab. 5 and Fig. 9), the pressure maximum is only of 5% lower than in case of civilian 5.56x45 mm Pb, but significantly lower (i.e. 12%) than for an RS military bullet. The pressure impulse is also significantly lower than in case of military 5.56 mm projectile. In this situation, the difference reaches approx. 30%, which should be taken into account during the rifle operation system design. Serious difference in a muzzle bullet momentum between 5.56 mm and 7.62 mm projectiles (7.62 mm reaches approx. 57% greater momentum than 5.56 mm) for such pressure impulse differences was provided by the bullet diameter ratio. Moreover, the mentioned fact strongly impacts on the rifle recoil and finally – on the soldier's fire accuracy. In case of ballistic, relatively stiff stand, the projectiles dispersion was better in comparison with the previously obtained results. It can be an effect of the greater bullet inertia and weaker influence of imperfections on the projectile flight.

Moreover, taking into account the data obtained in Tab. 6, significantly greater value of a drag coefficient was estimated. The most probable reason of these observations can be seriously lower the Mach number for the PS bullet.

Table 5. Summary of 7.62x39mm PS cartridge

No.	P_1	PI_1	P_2	PI_2	V_M	V_2	V_{25}	V_{50}	ΔV_{50}
	[MPa]	[MPa*ms]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[mm]	[mm]
1	296.4	141.0	734.8	730.7	709.3	687.9	46.9	-29.1	-49.8
2	284.2	138.1	738.0	732.1	710.5	688.1	49.9	-55.8	-60.4
3	303.9	137.4	750.8	741.7	720.2	696.9	53.9	2.0	-67.9
4	311.7	139.4	753.0	749.0	727.5	705.3	47.7	-16.2	-49.7
5	296.6	137.4	744.6	741.6	720.2	697.9	46.7	-19.3	-47.4
6	313.7	137.2	748.5	745.8	725.3	703.2	45.3	-30.8	-40.1
7	308.1	143.4	745.7	742.1	720.2	697.5	48.2	7.4	-30.5
min	284.2	137.2	734.8	730.7	709.3	687.9	45.3	-55.8	-67.9
max	313.7	143.4	753.0	749.0	727.5	705.3	53.9	7.4	-30.5
Δ	29.5	6.2	18.2	18.3	18.2	17.4	8.6	63.2	37.4
average	302.1	139.1	745.1	740.4	719.0	696.7	48.4	-20.3	-49.4

Standard / Type EPVAT pressure, L=520.0 mm, L_1=42.0 mm

Table 6. Estimated drag coefficient of 7.62x39 mm PS cartridge

No.	Mach number range [-]	Average Mach number [-]	Average drag coefficient [-]
1	2.02 ÷ 2.15	2.09	0.343
2	2.02 ÷ 2.15	2.09	0.346
3	2.05 ÷ 2.18	2.12	0.351
4	2.07 ÷ 2.20	2.14	0.338
5	2.05 ÷ 2.18	2.12	0.344
6	2.07 ÷ 2.19	2.13	0.333
7	2.05 ÷ 2.18	2.12	0.344
average		**2.12**	**0.343**

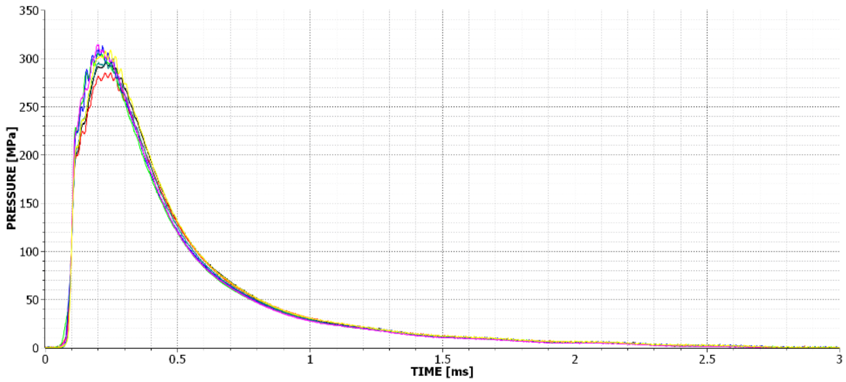

Fig. 9. Courses of pressure measured at L_1=42mm from a barrel inlet for 7.62x39 mm PS

3.4. .300 Blackout HP 125 gr

Ultimately, the .300 Blackout bullet was investigated. In this situation, the comparison with 7.62x39 mm ammunition is much more reasonable. The reason is the similarity in mass and geometrical properties of these projectiles. As it can be observed in Tab. 7 and Fig. 10-12, the peak pressure in case of .300 BLK is the highest among all investigated ammunition types, but relatively close to the value for 5.56x45 mm RS round. It is the effect of required pressure impulse, which is still significantly lower (10%) than the value for 7.62x39mm PS. This fact was reflected in the lower muzzle velocity. The registered results (the highest maximum pressure and the lowest pressure impulse) are the effects of application of the cartridge case, which is similar to the 5.56x45 mm one. Usage of the projectile, characterized by larger geometrical and inertial parameters, result in more intensive decompression of propellant gases, which impacts on serious pressure impulse decrease in comparison with other types of ammunition.

Moreover, comparing the projectile muzzle momentum with the 7.62x39 mm bullet, similar rifle recoil parameters can be expected.

What is extremely important, the .300 BLK ammunition definitely declassed other types of ammunition in the bullet dispersion at the distance of 50 m. What can be also observed in Tab. 8, the estimated drag coefficient was approx. 10% greater than the value for 7.62x39 mm. This discrepancy can be also explained by differences in a value of the Mach number (10%) and the imperfections of applied methodology for a drag coefficient estimation.

Table 7. Summary of .300 Blackout HP 125 gr cartridge

No.	P_1	PI_1	P_2	PI_2	V_M	V_2	V_{25}	V_{50}	ΔV_{50}	P_1	PI_1
	[MPa]	[MPa*ms]	[MPa]	[MPa*ms]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[mm]	[mm]
1	356.6	120.7	155.2	51.7	667.6	668.4	647.9	627.1	40.5	-27.0	-46.0
2	378.7	128.3	158.6	50.4	667.1	669.1	648.8	627.3	39.8	-34.3	-51.0
3	373.6	125.5	154.8	50.5	683.1	682.1	661.4	640.4	42.7	-35.8	-51.4
4	355.6	127.2	155.4	52.1	678.9	678.0	657.8	636.3	42.6	-33.8	-54.0
5	347.8	127.0	156.6	52.3	667.0	676.1	656.0	635.5	31.5	-29.9	-51.5
6	364.0	125.6	156.2	52.2	682.6	682.3	661.5	640.5	42.1	-30.2	-56.5
7	357.1	127.1	155.6	53.2	681.7	678.8	658.4	637.7	44.0	-36.3	-55.1
min	347.8	120.7	154.8	50.4	667.0	668.4	647.9	627.1	31.5	-36.3	-56.5
max	378.7	128.3	158.6	53.2	683.1	682.3	661.5	640.5	44.0	-27.0	-46.0
Δ	30.9	7.6	3.8	2.8	16.1	13.9	13.6	13.4	12.5	9.3	10.5
average	361.9	125.9	156.1	51.8	675.4	676.4	656.0	635.0	40.5	-32.5	-52.2

Standard / Type EPVAT pressure, L=406.4 mm, L1=37 mm, L2=107.4 mm

Table 8. Estimated drag coefficient of .300 Blackout HP 125 gr cartridge

No.	Mach number range [-]	Average Mach number [-]	Average drag coefficient [-]
1	1.84 ÷ 1.96	1.90	0.373
2	1.84 ÷ 1.97	1.91	0.380
3	1.88 ÷ 2.01	1.94	0.376
4	1.87 ÷ 1.99	1.93	0.375
5	1.87 ÷ 1.99	1.93	0.361
6	1.89 ÷ 2.01	1.95	0.365
7	1.88 ÷ 2.00	1.94	0.371
average		**1.93**	**0.372**

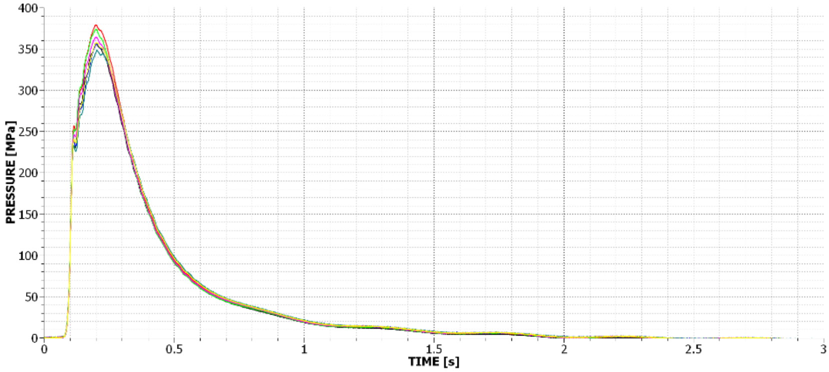

Fig. 10. Courses of pressure measured at L_1=37 mm from a barrel inlet for .300 Blackout HP 125 gr

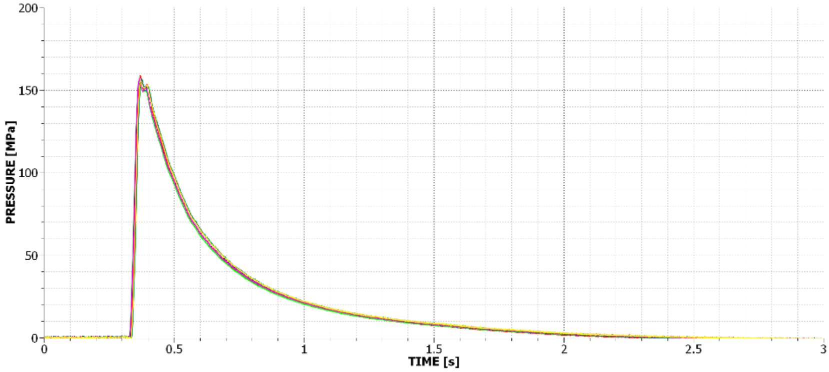

Fig. 11. Courses of pressure measured at L_2=107.4 mm from a barrel inlet for .300 Blackout HP 125 gr

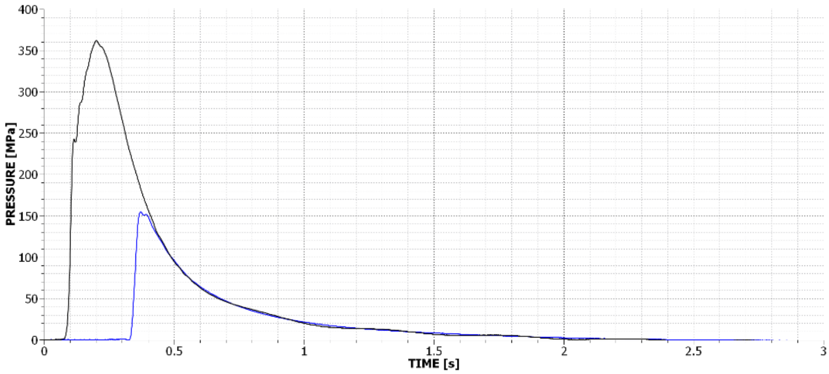

Fig. 12. Average courses of pressure measured for .300 Blackout HP 125 gr

3.5. Summary

Summarized data for investigated bullets were presented in Tab. 9 and Fig. 13-18. In order to highlight the accuracy of fire, the R_{100} radius was additionally calculated. As it can be seen, the .300 Blackout ammunition definitely declassed its rivals in this area – the estimated parameter was at least 3 times lower than in case of other investigated cartridges. Moreover, it can be noticed that despite the differences in the estimated drag coefficients, relative velocity decrease (drop) at 50 meters is similar for all types of the investigated rounds and is equal to approx. 6%.

Table 9. Summary of data

	P_1	PI_1	ΔV_{50}	ΔV_{50}	Ma	C_d	R_{100}
	[MPa]	[MPa*ms]	[m/s]	[%]	[-]	[-]	[mm]
.300 Blackout HP 125 gr	361.9	125.9	40.5	6.0	1.93	0.372	8.2
5.56x45 mm Pb	316.0	191.9	58.0	6.0	2.78	0.309	26.3
5.56x45 mm RS	340.6	205.9	45.2	4.8	2.68	0.283	33.1
7.62x39 mm PS	302.1	139.1	48.4	6.5	2.12	0.343	37.2

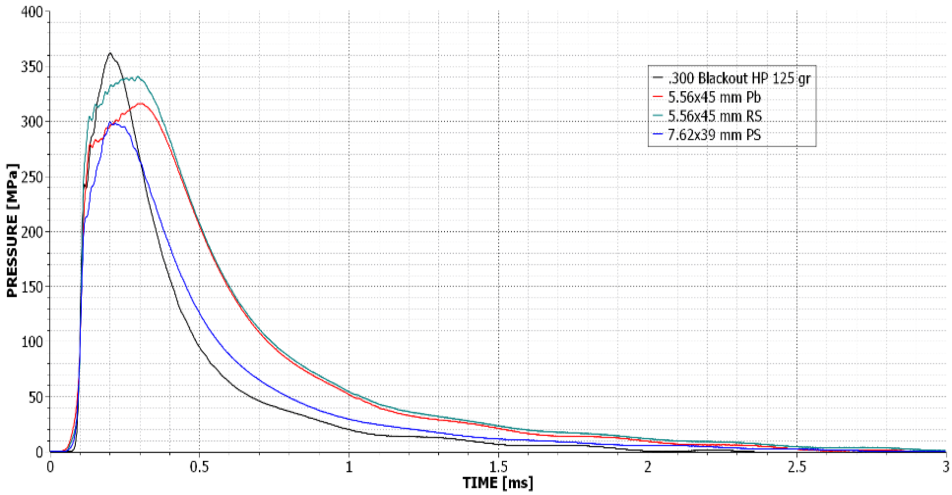

Fig. 13. Comparison of pressure for different intermediate cartridges

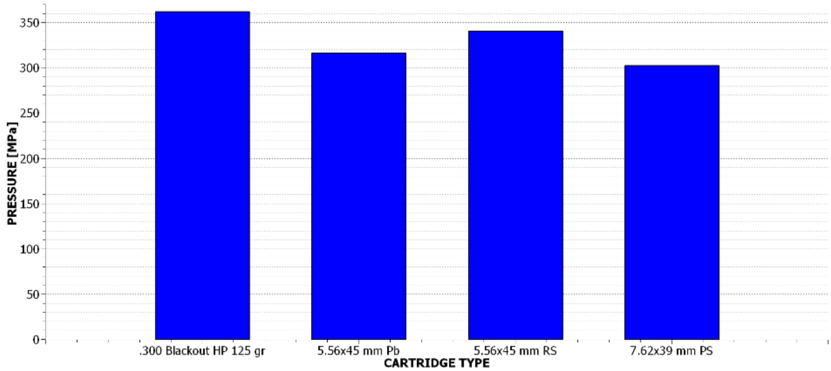

Fig. 14. Comparison of maximum pressure for different intermediate cartridges

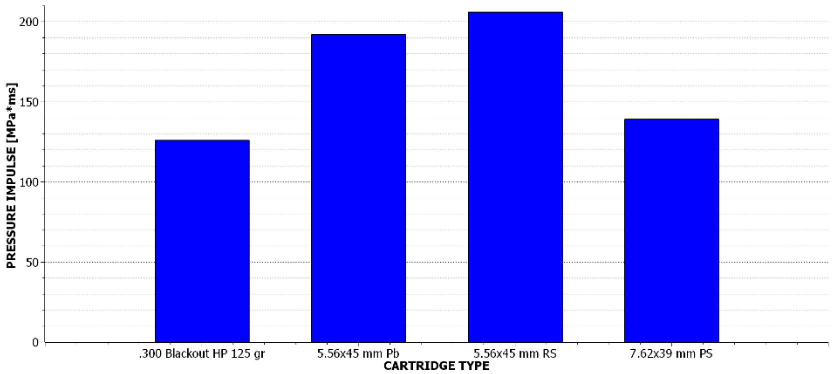

Fig. 15. Comparison of pressure impulse for different intermediate cartridges

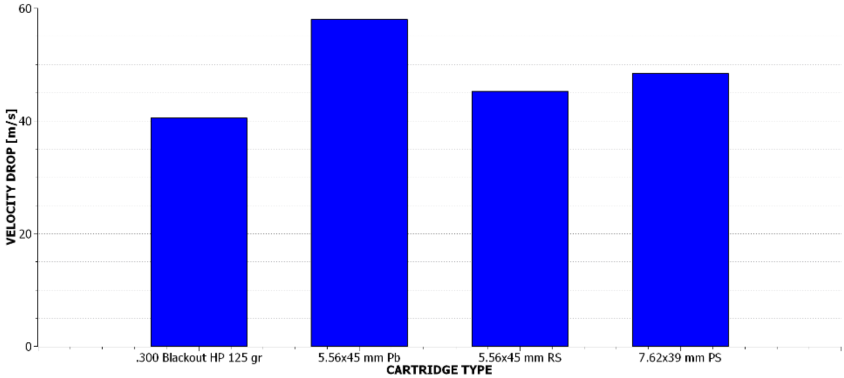

Fig. 16. Comparison of velocity drop for different intermediate cartridges

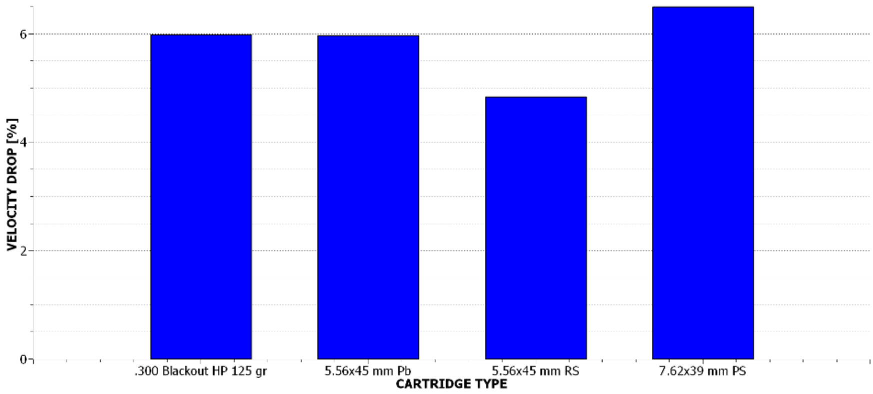

Fig. 17. Percentage comparison of velocity drop for different intermediate cartridges

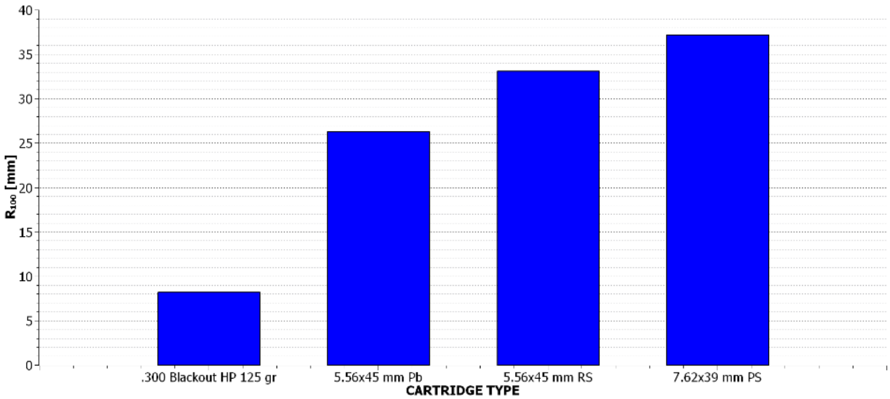

Fig. 18. Dispersion parameter R_{100} for different intermediate cartridges

4. CONCLUSIONS

- The presented methodology allowed for preliminary ballistic comparison of selected intermediate cartridges;
- As it can be concluded, application of the .300 BLK ammunition seems to be more reasonable in case of short barrels. The reason of this proposal is the fact, that a pressure-time course reaches the maximum value relatively early and the pressure intensively decreases after the extremal point;
- Taking into account the above-mentioned fact and differences in pressure impulses estimated for 5.56x45 mm and .300 BLK, it is necessary to include the observed discrepancies in conversion systems design;
- Comparing the fire accuracy for investigated bullets, the advantage of Hornady ammunition over MESKO can be seen;

- Dimensional analysis of the investigated cartridges, allows for recommendation in the exploitation safety area. Similarity of 5.56 mm and .300 BLK allows for loading the second one to the 5.56x45 mm magazine and chamber. This situation poses a serious threat for a user in case of a shot.

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REFERENCES

[1] Żuk B. Aleksandr. 2016. *Rifles, carbines and sub-machine guns. Encyclopedia of long military weapons of the XX century* (in Polish). Warsaw: Bellona, ISBN 978-83-11-13952-7.

[2] Williams G. Anthony, Jayesh Dhingra. 2018. *Jane's Weapons – ammunition 2018-2019.* IHS Jane's, ISBN 978-0-7106-3304-0.

[3] *Multi-calibre manual of proof and inspection (M-CMOPI) for NATO small arms ammunition.* NATO standard AEP-97.

[4] Litz Bryan. 2017. *Ballistic performance of rifle bullets.* Applied Ballistics LLC, ISBN 978-0-9909206-0-1.

[5] Fikus Bartosz, Zbigniew Surma, Radosław Trębiński. 2019. Preliminary Application Correctness Assessment of Physical Burning Law in Interior Ballistics Phenomena Modeling in Small-Caliber Guns. In *Proceedings of the 31st International Symposium on Ballistics*. USA: Destech Pubns Inc.

[6] Weinacht Paul, James F. Newill, Paul J. Conroy. 2005. *Conceptual Design Approach for Small-Caliber Aeroballistics with Application to 5.56-mm Ammunition*, US Army Research Laboratory, Report number ARL-TR-3620.

Wstępne badania porównawcze właściwości balistycznych amunicji pośredniej

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Streszczenie. W artykule przedstawiono wstępne wyniki badan porównawczych właściwości balistycznych amunicji pośredniej. W badaniach skupiono się głównie na weryfikacji poprawności przyjętych założeń oraz metod badawczych. Do badań wykorzystano ciśnieniowe lufy balistyczne wykonane zgodnie z normą NATO EPVAT. Zmierzono przebiegi ciśnień gazów prochowych w przewodzie lufy oraz prędkość pocisku w czterech punktach toru lotu. Obliczono impulsy ciśnienia, parametr R100 na odległości 50 m oraz średni współczynnik oporu aerodynamicznego dla poszczególnych rodzajów amunicji. Otrzymane rezultaty pozwoliły na wstępne porównanie właściwości balistycznych najpopularniejszych rodzajów amunicji pośredniej. Zdobyte doświadczenie i wyciągnięte wnioski pozwolą na uniknięcie pewnych błędów podczas przyszłych badań na większą skalę.

Słowa kluczowe: balistyka wewnętrzna, balistyka zewnętrzna, właściwości balistyczne, amunicja strzelecka