Lead and nonlead ammunition comparative tests

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Abstract:

To evaluate quality and usefulness of nonlead ammunition, we performed comparative tests of available ammunition. We tested an ammunition of most common calibers, with conditions of testing chosen to be equal or most close to its practical use. The objective of testing was precision, price, and in some cases also risk of ricochet. Most of nonlead ammunition seems to be precise enough for ordinary purposes, but not for sporting disciplines where precision is critical. Economical issues also come into account, as copper alloy bullets, which proved to be most precise of lead alternatives, are also most expensive. Moreover, these bullets also manifested strong inclinations to dangerous ricochets, as well as other possibly dangerous side effects.

1. Introduction

Lead-free ammunition is available in many calibers. However, there are concerns about its performance and safety. We performed comparative tests of available lead and nonlead ammunition. As we concentrated on practical aspects, we chose ammunition in calibers most often used for particular purpose, using firearms commonly used for these particular purposes, and setting shooting distances to values usual for these purposes.

2. Airgun pellets

We tested EXACT tin pellets of 4,5 mm caliber, weighing 0,440 g, from CZ manufacturer JSB Match Diabolo, using EXACT lead pellets weighing 0,547 g, from the same manufacturer, as control. To minimise other influences on precision that ammunition, we asked elite (4th place in the World) target shooter Pavel CINK to perform test with his customised target air rifle (PCP rifle Ataman MKII Benchrest, with muzzle energy set at 16J with lead pellets, grooves twist 16.5 inch – one full turn of bullet in 419 mm of barrel), set in the benchrest support. The distance was set at 25 meters in indoor range. For each ammunition, we shot four groups of five pellets.

Ammunition	Group 1	Group 2	Group 3	Group 4	Average disperse
Tin	< 1 mm	5 mm	4 mm	8 mm	4,25 mm
Lead	< 1 mm	< 1 mm	< 1 mm	< 1 mm	< 1 mm

Distance was measured between centers of two most distant hits. According to testing shooter, this disperse is sufficient for recreational shooting, but not for sport target shooting.

3. Rimfire ammunition

We tested COPPER-22 ammunition with bullet weighing 1,05 g, made from compressed polymer/copper dust material by US company CCI (the only nonlead .22 ammunition on market – manufacturer already stopped production, but some is still available). We chose medium quality target ammunition Lapua Midas + with lead bullets weighing 2,59 g as control. The same shooter as above used rimfire customised rifle Calfee Turbo, with grooves twist of 16.5 inch (one full turn of bullet in 419 mm of barrel) using benchrest support for testing. The distance was set at 50 m in indoor range. For each ammunition, we shot five groups of five rounds.

Ammunition	Group 1	Group 2	Group 3	Group 4	Group 5	Average dispersion
Copper / polymer	13 mm	29 mm	39 mm	34 mm	40 mm	31 mm
Solid lead	6 mm	7 mm	5 mm	7 mm	10 mm	7 mm

Distance was measured between centers of two most distant hits. According to testing shooter, this disperse is insufficient not only for target shooting, but (considering additional disperse caused by average shooter and firearm) even for recreational shooting or small game hunting.

We also found several side issues with COPPER-22 ammunition. When fired, they strongly smell by burned plastic. We only generally point to possible health effects of these fumes, as we couldn't find what plastic was used in their manufacture.
Hit point with COPPER-22 is about 7 cm above aim point set for lead ammunition. However, this

should be possible to correct with re-setting of sights.
The shot is considerably louder, indicating higher gas pressure.
COPPER-22 rounds are difficult to load by hand to chamber and require press by bolt to set into place. This may be caused by shape of the bullet, its material, or both.

4. Rifle ammunition

We tested four commonly available nonlead ammunition with lead sporting ammunition as control group. We chose 308 Win. caliber, as most common caliber for hunting and target shooting. Tested ammunition was:

Hornady Superformance International (monolithic copper alloy bullet with plastic tip)
Hornady Custom International (monolithic copper alloy bullet with uncovered expansion tip)
Sellier&Bellot XRG (monolithic copper alloy bullet with aluminium tip)
Sellier&Bellot TXRG (monolithic copper alloy bullet with plastic tip)
Sako Racehead HPBT (lead core / full metal jacketed bullet) (control group)

4.1. Precision

The same shooter as above used Accuracy International AX (308 Winchester 20” barrel with grooves twist of 10 inch - one full turn of bullet in 254 mm of barrel) rifle with bipod for testing. Target was set at distance of 100m on outdoor range in windless weather. For each ammunition type, two groups of five rounds were fired. We also measured speed of the bullet, using radar device Labradar.

S&B TXRG	**Dispersion (mm)**	**V_1 (m/s)**	**V_2 (m/s)**	**V_3 (m/s)**	**V_4 (m/s)**	**V_5 (m/s)**	**V_{avg} (m/s)**
Group 1	35	810	817	816	814	815	814,4
Group 2	32	815	812	810	814	817	813,2

S&B XRG	**Dispersion (mm)**	**V_1 (m/s)**	**V_2 (m/s)**	**V_3 (m/s)**	**V_4 (m/s)**	**V_5 (m/s)**	**V_{avg} (m/s)**
Group 1	65	778	780	779	783	783	780,6
Group 2	78	779	781	781	778	783	780,4

Hornady Custom	**Dispersion (mm)**	**V_1 (m/s)**	**V_2 (m/s)**	**V_3 (m/s)**	**V_4 (m/s)**	**V_5 (m/s)**	**V_{avg} (m/s)**
Group 1	32	788	787	782	776	784	783,4
Group 2	23	783	786	777	782	787	783,0

Hornady Superformance	**Dispersion (mm)**	**V_1 (m/s)**	**V_2 (m/s)**	**V_3 (m/s)**	**V_4 (m/s)**	**V_5 (m/s)**	**V_{avg} (m/s)**
Group 1	50	815	815	818	815	818	816,2
Group 2	42	816	815	818	817	816	816,4

SAKO Racehead HPBT	**Dispersion (mm)**	**V_1 (m/s)**	**V_2 (m/s)**	**V_3 (m/s)**	**V_4 (m/s)**	**V_5 (m/s)**	**V_{avg} (m/s)**
Group 1	16	804	805	803	803	805	804,0
Group 2	18	805	803	804	805	803	804,0

According to testing shooter, these values of disperse are sufficient for hunting purposes and for short-to-medium distance sport shooting where precision is not critical (for example, disciplines like dynamic rifle or shooting metal silhouettes). It is insufficient for any precision-based shooting disciplines.

4.2. Ricochets

We also tested ability of the bullet to deflect or create dangerous splinters upon impact on hard surface. For this purpose, we set a steel target at angle of 45 degrees vertically in the distance of 50 m. About one meter from the target in the direction of expected deflection, we set paper sheet 4 m long and 2 meters high. For each ammunition type, we shot one group of five rounds, changing paper after each group.

From perforation of paper sheets (see attached photographic evidence), we believe that nonlead monolithic bullets either deflected in whole or produced few large splinters. In our opinion, most probable mechanism is that front part of the bullet (which is cut to create petal deformation upon hitting the game animal) splinters off while solid back of the bullet deflects in whole. The lead-core bullet shattered upon impact, creating few large splinters (but still smaller than splinters from nonlead ammo) and countless of tiny splinters. Note that we used sporting full metal jacket bullets for this test; hunting semi-jacketed soft points bullets would probably fragment even more upon impact on hard surface.

We therefore assume that risk of dangerous richochets is significantly higher when using monolithic non-lead rifle bullets.
We also note interesting finding – measured vertically, nonlead bullets didn't deflect in the shooting direction, but deviated about 40 degrees up and down, creating two areas of deflection. We assume this can be caused by dynamics of deformation of the front part of the bullet, or by spin of the bullet, or both. Therefore, in the case of impact on horizontally sloped hard surface, like backstop of outdoor shooting range or the ground when missing game animal, fragments from monolithic bullet could deviate significantly to the sides, which can be dangerous especially while hunting in group. Lead ammunition also fragmented in similar wide angle, but it produced splash of smaller fragments which were spread fairly even.

We also noted that S&B XRG ammunition produced strong flash upon impact, with intensity comparable with muzzle flash. We therefore note possibility of setting fire, especially in dry weather.

5. Handgun ammunition

For testing handgun ammunition, we chose caliber 9 mm Luger as most common pistol round and .357 Magnum as most common revolver round.

For 9 mm Luger ammunition, we tested two different types of rounds. As we couldn't get any commercially made non-lead ammunition in this caliber, we made our own through handloading with bullets cast from zinc (99,9 %). First batch of ammunition was manufactured with aim for keeping technical specification of S&B factory ammunition, i.e. bullet of the same size (therefore lighter, 6 grams) and the same load of gunpowder (0,25 g), resulting in faster bullet (440 m/s). On photographs, these are marked as “fast zinc”. Second batch was manufactured with aim to attain the same outcome, i.e. amount of gunpowder was adjusted (0.226 g) to attain the same bullet speed as factory round (390 m/s). On photographs, these are marked as “normal zinc”. We used two control groups; S&B factory ammunition with full metal jacket bullets (8,03 g) and handloaded ammunition with cast lead bullets (9,5 g bullet + 0,25 g of gunpowder).
For .357 Magnum ammunition, we used Magtech First Defense 357 Magnum ammunition with 6.15 g monolithic copper alloy hollow point bullet. As control group, we used Magtech 357Mag (357Q) FMJ FLAT with 8.09 lead core full metal jacket bullet for short range precision tests and for richochets testing, and S&B 357 Magnum SJHP ammunition with lead core semi-jacketed holloe point bullet weighing 10.25 g for long range tests

5.1. Precision

5.1.1. Pistol ammunition precision

We shot five groups of five “fast zinc” rounds, four groups of five “normal zinc” rounds (we used last five rounds to test ricochets), five groups of five rounds with lead bullets and four groups of five rounds of S&B factory ammunition. Targets were set at distance of 50 m on outdoor range in slow wind weather. Test shooter was Erik Hanuš, one of the top local target pistol shooters.

Ammunition	**Dispersion 1**	**Dispersion 2**	**Dispersion 3**	**Dispersion 4**	**Dispersion 5**	**Dispersion average**
Fast zinc	146 mm	148 mm	107 mm	115 mm	165 mm	136,2
Normal zinc	120 mm	162 mm	71 mm	109 mm	-	115,5
Cast lead	100 mm	122 mm	113 mm	77 mm	87 mm	99,8
S&B lead FMJ	47 mm	69 mm	86 mm	62 mm	-	66,0

We consider this test to be indecisive. As all cast bullets, both zinc and lead, performed similar but both lead controls, cast and factory, performed differently, we assume that poor manufacturing of cast bullets influenced precision more than material. We shall repeat this test if and when we can obtain better quality nonlead bullets.

5.1.2. Revolver ammunition precision

We used Ruger GP - 161 revolver with 6-inch barrel for short range test, setting target at 15 m distance on outdoor range in windless conditions. Testing shooter was David karásek, target shooter of average ability. Shooting position was sitting with gun resting on support. We shot two groups of five rounds of nonlead ammunition, one group of five rounds of S&B full metal jacket ammunition, and one round of five rounds of solid lead ammunition. The disperse of hits was comparable among all types of ammunition (29 mm and 35 mm with copper, 25 mm for FMJ, 48 mm for lead). We therefore assume that monolithic copper-alloy ammunition is sufficient for short range sport shooting.

We used Great Gun Winchester mod. 1873 lever-action rifle for long-range test, setting target at 50m. We shot one group of five nonlead bullets and one group of five lead core semi-jacketed hollow point bullets. (We had only five rounds left for this test – these bullets are quite hard to obtain.) Testing shooter was Tomáš Trávníček, target shooter of above average ability. Shooting position was sitting with gun resting on support.

Ammunition	**Dispersion**
Monolithic copper alloy hollow point bullet	92 mm
Lead core semi-jacketed hollow point bullet	62 mm

If this would be consistent outcome, it would mean that this nonlead ammunition is barely sufficient for sport disciplines like shooting steel silhouettes, but not for long range target shooting. However, it is not possible to ascertain that from only five shots. We shall continue with tests when we shall obtain more testing ammunition.

5.2. Ricochets

We also tested handgun ammunition for possibility of dangerous richochets, which can happen during some sport disciplines, especially from steel targets. For this purpose, we set a steel target at angle of 45 degrees vertically in the distance of 50 m. About one meter from the target in the direction of expected deflection, we set paper sheet 4 m long and 2 meters high. For each ammunition type, we documented in photograph outcome of the first shot and of five-shot group.

Judging by perforation of paper sheet, 357 Magnum copper alloy monolithic hollow point bullets deflected basically in whole, with few small additional splinters probably created by shattering of deformation zone in front part of the bullet.

Full metal jacketed lead core bullets of 357 Magnum caliber produced splinters of medium size.

Solid lead bullets of 357 Magnum caliber produced splash of tiny fragments.

Zinc 9 mm bullets fragmented irregularly – from perforation of paper sheet, we suppose that most bullets lost some weight in small splinters but kept most of their mass in one piece.

(Unfortunately, we didn't have 9 mm solid lead ammunition available when testing ricochets, and owner of the range where we tested precision forbade us from testing richochets, citing safety concerns.)

Ammunition	**Cost (CZK)**
Lead airgun pellets (EXACT JSB)	1.02
Tin airgun pellets (EXACT JSB)	0.945
Lead .22 (Lapua Midas +)	6.50
Copper/polymer .22 (CCI COPPER - 22)	6.30
Copper alloy .308 (Hornady Custom)	61.15
Copper alloy .308 (Hornady Superformance)	77.30
Copper alloy .308 (S&B XRG)	44.00
Copper alloy .308 (S&B TXRG)	45.00
Lead core full metal jacket (SAKO Racehead)	39.00
Copper alloy .357 Magnum (Magtech First Defense)	19.40
Lead core full metal jacket .357 Magnum (Magtech FMJ FLAT)	8.70

6. Conclusion

Among lead substitutes for ammunition manufacturing, copper alloy bullets are currently most technologically advanced. These substitutes are sufficient for hunting and police/defensive shooting, although they are not as good as current lead ammunition, and cost significantly more. For other purposes and materials, nonlead ammunition is either unavailable or of insufficient quality.
Given softness and malleability of lead, bullets made from its substitutes are also more prone to dangerous ricochets. This is especially true for copper alloys, which are most hard from all considered substitutes, except for steel.

Selected photographic evidence is attached in zip archive.

Complete photographic evidence in high resolution can be downloaded at:

https://gunlex.cz/en/3595-comparative-test-of-lead-and-nonlead-ammunition
or
https://gunlex.cz/clanky/hlavni-clanky/3594-komparacni-test-oloveneho-a-neoloveneho-streliva