DOI: https://doi.org/10.52651/sam.a.2024.2.29-35

INFLUENCE OF BULLET SHAPE ON .223 REMINGTON AMMUNITION ACCURACY ANALYSIS

Tomáš RÁZGA, Peter BALÁŽ, Michal MOZOĽA,Vratislav KREHEĽ

Abstract: The quality of ammunition significantly affects the accuracy of small-caliber weapons. Many articles emphasize the importance of well-made ammunition. There is a wide variety of .223 Remington ammunition available from local manufacturers, often with a typical 55-grain bullet weight but different bullet shapes. This article discusses the measured results of different bullet shape dispersions and possible causes of these adverse events.

Keywords: Bullet shape; Accuracy; Ammunition; Powder charge.

1 INTRODUCTION

The quality of ammunition is as important as the quality of the weapons that soldiers use. Since the 1960s, 5.56x45 mm ammunition, known in civilian circles as .223 Remington, has been very popular. The differences between these two are small, but can have a large impact on performance, safety, and weapon function.

The first one is the higher pressure level of the 5.56 NATO cartridge, which can approximately jump up to 450 MPa. The .223 Remington´s maximum pressure load is approximately 430 Mpa. The second one and the most important difference is that a 5.56 NATO chamber has a .125” longer throat. This allows one more grain of powder to add into a 5.56 NATO cartridge, giving it higher performance than its .223 Remington counterpart.

The most significant issue with these differences is during firing with a rifle chambered for .223 Remington with 5.56 NATO ammunition. Due to the longer throat of the NATO chamber, this combination will cause the pressure increase at approximately 450 MPa or more the .223 chambered weapon, which is 50 MPa higher than the .223's normal functional pressure of 400 MPa. This is not safe and can cause primers to back out or worse, can harm the operator, the rifle, or both.

Conversely, firing a .223 Remington cartridge in a 5.56 NATO chambered rifle can result in suboptimal performance due to the throat difference. The .223 Remington’s 380 MPa will not be attained, thus hurting velocity and performance. Problems start occurring when this combination is fired out of a 5.56 NATO chambered rifle with a 14.5” (or shorter) barrel. The lower powder charge of the .223 round, coupled with the pressure drop in the 5.56 NATO chamber, will cause the rifle to cycle improperly. NATO chambered rifles with barrels longer than 14.5” should function properly when firing .223 Rem ammunition.

The .223 Remington is one of the most common rounds in the world. It is very versatile and popular for hunting, military, and sport shooting. The typical bullet weight ranges from 40 to 90 grains, depending on the weapon twist.

Tab. 1 Parameters of .223 Remington round with 55grs bullet

Type of brass	Rimless
The bullet diameter (mm)	5,7
The neck diameter (mm)	6,4
The brass thick (mm)	1,1
The crimp diameter (mm)	9,0
The brass length (mm)	45
The maximum pressure (MPa)	430
The maximum overall length (mm)	57,4
The type of primer	Boxer

Source: authors.

The good modern rifle should make dispersion closer to 1 MOA (Minute of angel), which means that dispersion of shots is smaller than 29mm at 100m. For example soviet era made SVD Dragunov should have efficiency 1,5 MOA with 7,62x54 mm round.

A lot of sport shooters and hunters made their own ammunition. This kind of process is known as a reloading. They can make more quality rounds than mass industry.

A lot manufactros made typical .223 Remington 55 grs weight bullets but bullets have different shape. When we read reloading manual a we want to use some kind of gunpowder, we always find how many of gunpowder we should use to bullet of some weight. Based on this is shape of bullet not as important as a weight of bullet.

2 THE EFFECTS OF RIFLE BULLET SHAPE

Looking back at the history of projectiles, the earliest jacketed bullets were round-nosed, reminiscent of the lead bullet designs from the mid to late 19th century.

At moderate ranges, these bullets provided everything hunters and shooters needed: adequate accuracy, a weight-forward design that improved straight-line penetration, and a compact length-to-width ratio that fit efficiently in the cartridge case.
As the 20th century approached, and particularly following the Spanish-American War, the U.S. Army decided to update its .30-40 Krag cartridge, opting for the .30-03, which retained the Krag's 220-grain round-nose bullet. However, within just three years, the U.S. followed the example of European designers by modifying the ’03 case and adopting a lighter, pointed spitzer bullet. A boat tail - almost as important as the pointed tip - was introduced to enhance the bullet's aerodynamic properties at longer ranges, resulting in a flatter trajectory and better retained velocities as distance increased.

Interestingly, the boat tail design had appeared as early as 1901, illustrating the rapid advancements in ballistic science. Fast forward to 2020, and you’ll find all these designs still available and performing well, each for its unique advantages. Let's explore the benefits and drawbacks of these different rifle bullet designs to help guide your decision-making process.

2.1 The roundnose bullets

Round-nose bullets remain a popular choice among classic cartridge enthusiasts and can still be effective for hunting, as long as the shooting distances aren’t too great. For this discussion, I’ll also include flat-nose bullets, as their performance is quite similar.

The main limitation of round-nose bullets is their low ballistic coefficient (BC) - which measures how efficiently they travel through the air. This lower BC causes their velocity to drop off significantly beyond 200 meters.

2.2 The spitzer design

When we shift to the spitzer design, there's a clear advantage in trajectory, especially for longer shots. Boat tail spitzers, particularly modern iterations, are marvels of design, with an incredible amount of science behind them - nearly perfecting the projectile. Both target and hunting bullets fall into this category, making them a top choice for those hunting in open plains or mountainous regions where windy conditions can be a significant challenge. For long-range precision shooters - those who hit targets beyond 1,000 yards and sometimes even past a mile - this bullet profile is indispensable, as no other design offers the same level of performance at extended distances.

For target shooters, the discussion almost always centers around the boat tail spitzer. These bullets boast the highest ballistic coefficient values, making them the go-to choice. However, it's worth noting that in cup-and-core designs, they can be susceptible to jacket and core separation.

3 THE EXPERIMENT

For the practical experiment we use numerous types of bullets and rounds. The mass industry is represented by FIOCCHI .223 Remington FMJ. As the name suggest the bullet is full metal jacket round without boat tail. The weight of the bullet is 55grs.

Tab. 2 Parameters of FIOCCHI .223 Remington round with 55grs bullet

The type of the bullet	FMJ
The weight of the bullet (grs)	55
Muzzle velocity (m/s)	980
Muzzle energy (j)	1711
Bullet path at 100m (cm)	0
Bullet path at 200m (cm)	-8
Bullet path at 300m (cm)	-35
Bullet path at 400m (cm)	-87
Ballistic coefficient G1(lb/in^2)	0,195

Source: authors.

Fig. 1 FIOCCHI .223 Remington round with 55grs bullet
Source: authors.

3.1 The reloading of own rounds

For the practical experiment we also used 4 types of 55 grs bullets:
- .224 RN 55grs from H&N Sport;
- .224 SP 55grs from Sellier & Bellot;
- .224 FMJ 55 grs from Sellier & Bellot;
- .224 Blitzking 55 grs from Sierra.

RN means round nose bullets. These are typically pistol bullets with a semi circular nose. They can also be found in rifle calibers, but this is more rare. This RN bullets have flat-base design.

FMJ means full metal jacket bullets. Similar to FMJ are SP bullets, soft point. Soft-point bullets offer more expansion than a full metal jacket bullet and greater penetration than a hollow point. A soft-point bullet is essentially a full metal jacket bullet, which has a lead core wrapped in a hard copper casing, with the lead tip exposed at the nose of the bullet. To make a full metal jacket, the copper shell or "cup" of the bullet is made with an opening at the bottom, allowing lead to be poured inside. Because of the manufacturing process, full metal jackets usually have exposed lead at the rear. Both, SP and FMJ are not totally sharp. FMJ bullets have boat tail and SP bullets have flat-base.

According Sierra company, the Blitzking type of bullet should be one of the most accuarate bullet types. The nose tips of bullets are made of a proprietary acetyl resin compound, and the sharp tips improve the ballistic coefficient over the traditional flat-base Spitzer bullet design. The 55 grain has a boat tail to further increase ballistic coefficient compared to a flat-base design in these bullet weights.

Fig. 2 Types of bullets which were use in experiment. From left to right: RN type, FMJ type, SP type and Blitzking design
Source: authors.

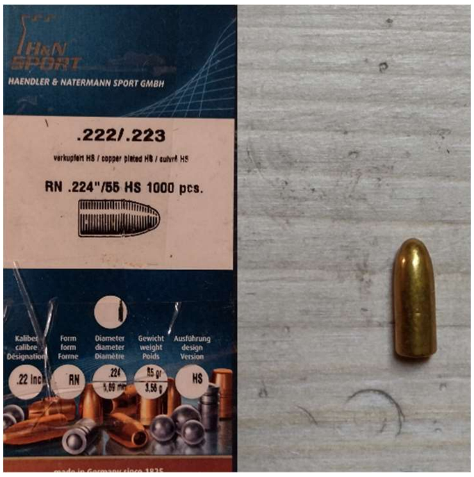

Fig. 3 .224 RN 55grs from H&N Sports
Source: authors.

Fig. 4 .224 SP 55grs from Sellier & Bellot
Source: authors.

Fig. 5 .224 FMJ 55grs from Sierra
Source: authors.

Fig. 6 .224 FMJ 55grs from Sierra
Source: authors.

For laboration we used single operation press LEE Precision Breech Lock Challenge Press. We use onetime shot brasses, which all of them were from Sellier & Bellot company. All cartridge cases were cleaned a reformed by Full length sizer die. We also cleaned the neck of cartridge and his primer seat. As a new primer were used 4,4 mm Small pistol primers from FIOCCHI Company. We have a lot of good experimencies with this primer manufacor. Primers are reliable and very suitable for .223 remington rounds despide that they are made for pistols and revolvers. .223 Remington is rifle round but there is not a big pressure and due to that we are not force to use rifle primers, which are a little stronger than pistol one.

After that we set new primer. Primer was manufactured by FIOCCHI and it was Small pistol 4,4 mm. We used LOVEX D-073,4-03 gunpowder. According loading manual we used 1,60 g of gunpowder for each round.

Fig. 7 4,4 mm Small pistol primers used in our rounds
Source: authors.

Fig. 8 LEE Precision Breech Lock Challenge Press
Source: authors.

All cartridge cases were adjusted by Lyman Case Prep Xpress for the exact case lenght. There were cleaned and prepared primer seat and case neck for setting a bullet. All cartridge cases had similar lenght.

Fig. 9 Lyman Case Prep Xpress
Source: https://www.amazon.ca/Lyman-Case-Prep-Xpress-115-Volt/dp/B004TABTWU

Fig. 10 Cleaning primer seat at Lyman machine
Source: https://www.amazon.ca/Lyman-Case-Prep-Xpress-115-Volt/dp/B004TABTWU

Fig. 11 The lubrication and cleaning case neck
Source: https://www.amazon.ca/Lyman-Case-Prep-Xpress-115-Volt/dp/B004TABTWU

Fig. 12 The adapting case neck for seating a bullet
Source: https://www.amazon.ca/Lyman-Case-Prep-Xpress-115-Volt/dp/B004TABTWU

D-073,4 is two-component dense spferic gunpownder, which is one of the most popular gunpowder for reloading .223 Remington ammunition in the world. In contrast with pistol gunpowder, grains of this powder has different shape and burning rate is not as fast as spherically powder.

Fig. 13 D-073,4 gunpowder
Source: authors.

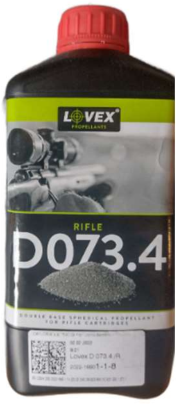

Fig. 14 D-073,4 gunpowder
Source: authors.

Fig. 15 The most popular gunpowders
and their grains
Source: authors.

3.2 THE SHOOTING TEST

For shooting part was used AR-15 base rifle PAR Mk-3. We were shooting at open air shooting range situated in Liptovské Sliače area. The shooting conditions were favorable, with a temperature of 5 degrees Celsius and minimal wind interference. The cool temperature provided stable air density, contributing to consistent bullet trajectory. Visibility was clear, and overall conditions allowed for precise testing without significant environmental factors affecting the results.We were shooting at distance of 100 metres, due to fact, that we want to calcute accuracy in MOAs. Shooter (author) was shooting from the prone position and used bipod. We wanted to get close to combat conditions and due that fact, we did not use stative stand. If we consider possibilities of shooter´s errors, we selected from this experiment one best series consisting of the best 5 shots, from the total number 15 shots.

Each of the shots was shot through the chronometer what is a machine, which calculate speed of the bullet. The fact, that gas escaping from the muzzle and it may affects our results, the chronometer was 1m away from the rifle of the muzzle.

At next series of pictures we could see impact of bullet shape on hit dispersion (yellow circle). As we could see there is a notable difference between hits (red circles), mainly between aiming point (green cross) and middle hit (yellow cross).

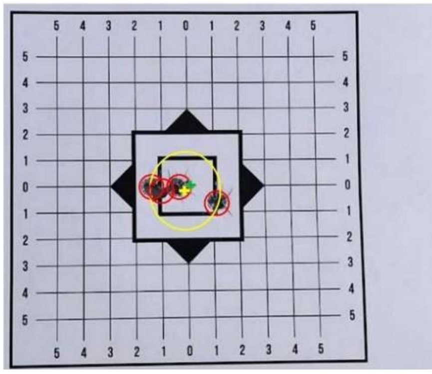

Fig. 16 Accuracy of Blitzking bullets
Source: author.

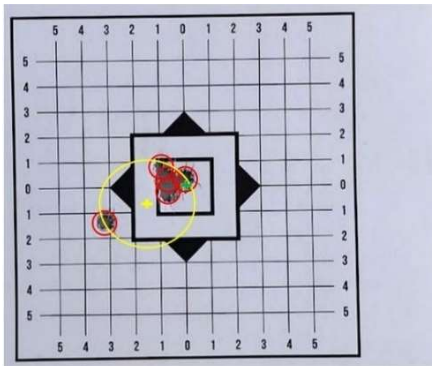

Fig. 17 Accuracy of FIOCCHI factory 223 Remington rounds
Source: authors.

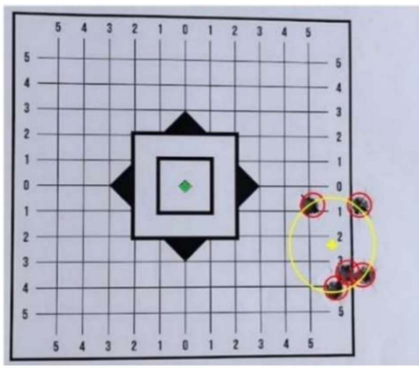

Fig. 18 Accuracy of FMJ bullets
Source: authors.

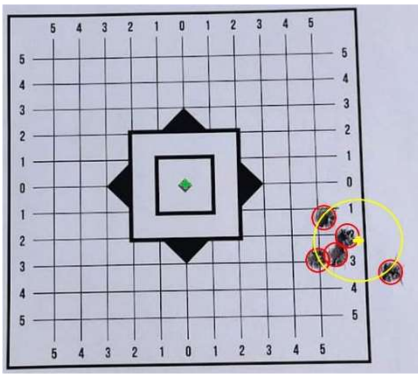

Fig. 19 Accuracy of SP bullets
Source: authors.

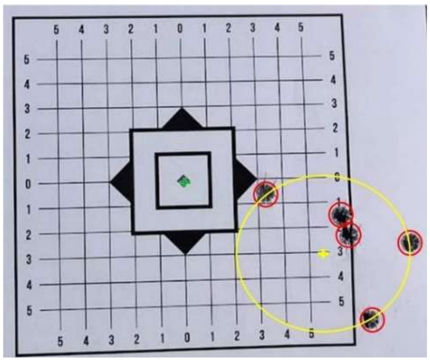

Fig. 20 Accuracy of RN bullets
Source: authors.

As we can see there are important differences in accuracy between each series. The best result was made with Blitzking bullets. The rounds, which do not have on bullet boat tail, had significant worse dispersion and position of middle hit was displaced to the right down side.

This is due to fact, that rifle has 1:8 right turn twist rate and 16 inch barel. Rounds with SP and RN bullets have smaller muzzle velocity and stabilization did not work properly. Another thing which had impact was that, SP and RN bullets are shorter and do not have exact aerodynamical shape.

Tab. 3 Parameters of FIOCCHI .223 Remington round with 55grs bullet

Bullet	Dispersion (diameter in mm)	Distance between middle hit and aiming point (mm)
RN	69	68
FMJ	35,5	
FMJ FIOCCHI	37	17
SP	32,5	62,5
BLITZKING	27,5	4

Source: authors.

Tab. 4 Muzzle velocity

Bullet	Muzzle velocity (m/s)
RN	880
FMJ	923
FMJ FIOCCHI	973
SP	940
BLITZKING	955

Source: authors.

Statistical analysis was conducted to evaluate the significance of the differences observed. The mean dispersion (in cm) and standard deviation for each type of bullet are presented in Table 3.

Tab. 5 Mean dispersion

Bullet type	Mean Dispersion (cm)	Standard Deviation (cm)	Muzzle velocity (m/s)
FMJ	2,3	0,5	880
HP	3,1	0,7	923
SP	4,2	1,0	973

Source: author.

The mean dispersion for each bullet type was calculated using the formula:

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (1)$$

where n is the number of measurements and x_i are the individual dispersion values.

Based on the experimental results, the mean dispersion and standard deviation for each bullet type were calculated. The standard deviation was determined using the following formula:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2} \quad (2)$$

The FMJ bullets had a mean dispersion of 2.3 cm with a standard deviation of 5 mm, indicating high consistency and stability in flight. The HP bullets exhibited a mean dispersion of 31 mm with a standard deviation of 7 mm, suggesting slightly higher variability, likely due to their design, which can affect aerodynamic performance. The largest dispersion was observed with the SP bullets, with a mean value of 42 mm and a standard deviation of 10 mm, potentially caused by the deformation of the soft tip upon firing. Statistical analysis, including a t-test, showed that the differences between the mean dispersions of FMJ and HP bullets are statistically significant at the 5 % significance level (p-value 0.03), highlighting the importance of bullet shape for shooting accuracy.

A t-test was performed to compare the means of FMJ and HP bullets, resulting in a p-value of 0.03, indicating a statistically significant difference at the 5 % significance level. A t-test was performed to compare the mean dispersions of FMJ and HP bullets, calculated as:

$$t = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{\frac{{s_1}^2}{n_1} + \frac{{s_2}^2}{n_2}}} \tag{3}$$

where x_1 and x_2 are the mean values, s_1 and s_2 are the standard deviations and n_1 and n_2 are the sample sizes for bullets respectively.

4 CONCLUSION

The results indicated significant differences in the dispersion patterns between the different bullet shapes. The FMJ bullets showed the tightest grouping, suggesting higher consistency and stability in flight. The HP bullets had a slightly larger dispersion, likely due to their design, which can cause variations in aerodynamic performance. The SP bullets exhibited the largest dispersion, which might be attributed to the softer tip deforming upon firing.

These findings align with previous studies that have highlighted the importance of bullet design in ammunition performance (Smith & Wesson, 2020; Brown, 2019). The higher dispersion of HP and SP bullets may also be linked to variations in manufacturing processes and material properties.

Furthermore, the analysis suggested that environmental factors, such as wind and temperature, had a minimal impact on the dispersion patterns observed. This reinforces the conclusion that bullet shape is a critical determinant of accuracy in .223 Remington ammunition.

References

[1] CARLUCCI, E. and JACOBSON, S. *Ballistics: Theory and Design of Guns and Ammunition*. 2013. 612 pages. ISBN: 978-1-4557-3131-3. https://doi.org/10.1201/b15495

[2] RINKER, A. *Understanding Firearm Ballistics*. 2018. 496 pages. ISBN: 978-1-61039-025-3.

[3] SMITH, J. *Cartridge Reloading in the Twenty-First Century*. 2012. 320 pages. ISBN: 978-1-61608-832-2.

[4] MCCOY, R. L. *Modern Exterior Ballistics.* U.S. Army Research Laboratory, 2005. Available at: https://apps.dtic.mil/sti/pdfs/ADA441359.pdf

[5] DAKIN, J. and MURPHY, C. The Forensic Analysis of Ammunition and Ballistics. In *Journal of Forensic Sciences*, 2021, 66(5), 1234-1245. Available at: https://onlinelibrary.wiley.com/doi/full/10.1111/1556-4029.15152

Dipl. Eng. Tomáš **RÁZGA**
Armed Forces Academy of General M. R. Štefánik
Department of Mechanical Engineering
Demänová 393
031 01 Liptovský Mikuláš
Slovak Republic
E-mail: tomas.razga@aos.sk

Dipl. Eng. Peter **BALÁŽ**
Armed Forces Academy of General M. R. Štefánik
Department of Mechanical Engineering
Demänová 393
031 01 Liptovský Mikuláš
Slovak Republic
E-mail: peter.balaz@aos.sk

Dipl. Eng. Michal **MOZOĽA**
Armed Forces Academy of General M. R. Štefánik
Department of Mechanical Engineering
Demänová 393
031 01 Liptovský Mikuláš
Slovak Republic
E-mail: michal.mozola@aos.sk

Dipl. Eng. Vratislav **KREHEĽ**
Armed Forces Academy of General M. R. Štefánik
Department of Mechanical Engineering
Demänová 393
031 01 Liptovský Mikuláš
Slovak Republic
E-mail: vratislav.krehel@aos.sk

Tomáš RÁZGA was born in 1995 in Ružomberok. He is currently studying internal PhD. at Department of Mechanical Engineering in Armed Forces Academy of General M. R. Štefánik. His research area mainly includes small arms and ammunition.

Peter BALÁŽ was born in 1995 in Liptovský Mikuláš. He received his M.Sc (Eng.) at the Armed Forces Academy in Liptovský Mikuláš in 2020. He started his dissertation studies in 2023 at Department of Mechanical Engineering in Armed Forces Academy of General M. R. Štefánik. His research area mainly includes small arms and ammunition.

Michal MOZOĽA was born in Krupina, Slovakia in 1988. He received his M. Sc (Eng.) at the Armed Forces Academy in Liptovský Mikuláš in 2017. He started his dissertation studies in 2022. His research interests are focused on the optimisation of automatic weapon fire modes. He is currently working as an assistant professor at the Department of Mechanical Engineering in Armed Forces Academy of General M. R. Štefánik in Liptovský Mikuláš.

Vratislav KREHEĽ was born in Liptovský Mikuláš, Slovakia in 1972. He received his M.Sc (Eng.) at the Military Academy in Liptovský Mikuláš in 2003. He started his dissertation studies in 2021. His research interests are focused on optimization of sniper weapons fire mode. He is currently working as an assistant professor at the Department of Mechanical Engineering in Armed Forces Academy of General M. R. Štefánik in Liptovský Mikuláš.