Dynamic Stability – Projectiles

Ever observed elongated holes in your paper, cardboard or plastic targets when shooting at long range. When your projectiles seem to drop off line and enter the target sideways there is obviously a problem.

This effect is commonly called the "Key-holing" effect. The hole in the target is no longer circular, but oval, or shaped like the keyhole in a lock.

In the first paragraph I stated that this was at long range. Quite an ambiguous statement. When I refer to long range I refer to a range where the projectile is at the end of the supersonic regime in flight. This obviously changes when shooting at different altitudes and temperature. For arguments sake, we will assume all firings are at sea level (1013.2mb), in this paper and the temperature is a standard of 15 deg C.

A 30 calibre 168gn Sierra Match King (SMK) launched at 2680fps will end it's pure supersonic flight at or around the 700m mark. In my experience over the years I have seen this projectile to start "Losing it" around the 600m mark. When I mean "losing it", I mean one or two out of five will unexplainably hit somewhere around the target, sometimes up to a metre away.

Most shooters will assume that there is not enough Gyroscopic Stability(1)present for the projectile which means that there may not be a fast enough twist in the rifle barrel. Don't get me wrong, increasing twist rate can benefit in some cases, but when this is happening at these sorts of ranges, it is not due to a lack of Gyroscopic Stability, it's because there is a lack of Dynamic Stability(1).

<u>Down Range</u>

Gyroscopic Stability actually increases down range because the rate of spin per unit of forward travel actually increases. The projectile loses forward velocity a lot faster than it's rotational velocity (Spin). If a key-holing effect was noticed at a closer range such as say, 200m, then the barrel's rate of twist would certainly have to be looked at first.

<u>Dynamic Stability</u>

The area of dynamic stability is not only a much more complex subject, but the factors affect this and the forces that change stability are very hard to measure. The factors affecting dynamic stability are much more subtle and are generally only observed when the projectile is down range at or in the Transonic Zone(2). The transonic zone being the area of flight where the projectile is no longer 100% supersonic. This starts occurring at Mach 1.2 or at around 1350fps at sea level. The end of this zone is at Mach 0.8 or around 900fps where by the projectile is 100% subsonic. It is this zone that can cause big troubles for some projectiles. Having to negotiate this zone with the large changes in aerodynamic forces can be strenuous on projectile flight.

A projectile with adequate dynamic stability will survive this zone and keep travelling along it's intended flight path. An example of this, is the 30 calibre 175gn SMK. This projectile fly's extremely well through the transonic zone. The United States Military adopted it in 2001 for use in .308 calibre sniper rifles(3). This ammunition(4) is produced at the Lake City Plant by ATK Armament Systems Group.

Over 40 years ago Sierra manufactured the 30 cal 168gn Matchking for 300m competition shooting. This projectile was, and still is used extensively by many competition shooters and Law Enforcement snipers for close range precision shooting.

Earlier I mentioned that some serious stability issues were observed using the 30 cal 168gn SMK out past 600m. This was in the year 2001 when I was using these in the factory loaded Winchester Supreme line of ammunition. One or two out of five would literally miss the target by sometimes more than a metre. Over the next few years of reducing errors in the whole shooting system, it was narrowed down to this projectile. Isolating a possible cause is all about reducing errors, and believe me there are many errors that can be reduced in precision long range shooting.

As a result, any cartridges containing this projectile were kept aside for other uses and the Federal Gold Medal Match containing the Sierra 175gn Matchking was used from then on. The first piece of literature I read that really contained some sort of an explanation was Brian Litz's book, "Applied Ballistics for Long Range Shooting". Page 161 of this book, explains exactly why this projectile simply does not work for long range shooting.

Basically it boiled down to mass imbalance and the 13° angle Boat tail. This caused the projectile to lack Dynamic Stability when entering the Transonic Zone, causing it to develop significant amounts of Yaw(5). In fact this projectile rarely survives this zone.

Predicting Dynamic Stability

As dynamic instability occurs well away from the muzzle of the rifle, predicting it can prove to be very difficult. You cannot simply look at a projectile or shoot it at close range and make some sort of prediction as to whether it is dynamically stable or unstable. The only sure way to do this is to fire it at long range targets and see the results for yourself. If a match grade projectile has a steep boat tail angle (over 10°), you would have to question it's performance in long range flight.

It is possible to reduce the amount of yaw at longer ranges by increasing the twist rate of the barrel or by launching the projectile "a lot" faster, however it is not possible to predict what twist rate is required to arrive at an acceptable amount of yaw reduction.

Excessive Drag at Close Ranges

Spending more than two years observing the flight/ trajectory performance of the .338 cal 250gn SMK, a stability issue was also seen. This was not at long range but was at a much closer range. These projectiles launched from a .338 Lapua Magnum (LM) cartridge entered the transonic gateway at around 1200 metres in distance, at an altitude of 180m above sea level and temperature ranges within 15 – 25° Celsius. It's starting G1 BC was around the .587 mark. The average G1 BC required to get the projectile to hit it's mark at 1000m needed to be around the 0.646 area. Why was this so?

Approx 3000 rounds were fired over these two years it was ascertained this projectile required at least 600 -700m of travel to go to sleep. When it did, the average G1 BC jumped right up. This made it very difficult to accurately predict the flight path of this projectile using today's portable ballistic software systems. This degree of instability or more correctly stated,"drag from excessive yaw", never worsened after the 700m mark, in fact it always dramatically improved. Cartridges containing this particular projectile were no longer used for this reason.

Tangent and Secant Ogives

Projectiles that have a Tangent Ogive(6), generally have better dynamic stability by having more weight in the front. The projectiles tend to survive the transonic zone better and are more commonly used for extreme range shooting well outside the transonic zone. The BC of these projectiles are a little less than those exhibiting a Secant Ogive in the supersonic zone. However, the BC of Tangent Ogive projectiles are usually better once inside the subsonic area.

Projectiles constructed with a Secant Ogive, generally have a higher BC in the supersonic zone but due to their shape, have less dynamic stability in the transonic and subsonic zones. The BC of these projectiles therefore suffers in these areas. Shooter using Tangent Ogive projectiles should try to keep these inside the supersonic zone for best results.

Conclusion

Most projectiles will not have problems with Dynamic Instability. When possible, try and keep your targets within the supersonic regime. If you are in doubt where this distance lies, please visit www.jbmballistics.com and use the trajectory predicting online software to estimate the transonic gateway using the factory BC provided by the projectile manufacturer at their online store.

Avoid using the Sierra 30 cal 168gn SMK and the 338 cal 250gn SMK projectiles for long range shooting. Although Sierra Bullets undoubtedly create some of the finest precision projectiles in the world, these two will cause frustration in the field.

Two replacement projectiles for long range shooting in these two calibres by Sierra are the magical 30 cal 175gn SMK and the 338 cal 300gn SMK.

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References

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