RPM Test; a tale with three twists

Chapter I

So why is it that when we push our cast bullet out of our accurate 30-06 we get very good accuracy at 1800 fps or so but when we push the bullet to 2100 fps we get pretty poor accuracy? Is there really an RPM threshold for cast bullets which establishes where the accuracy capability will deteriorate if the RPM threshold is exceeded? That seems to be the question. Just what do we mean by “RPM threshold”:

The RPM threshold is that point where accuracy begins to deteriorate when the RPM is sufficient to act on imbalances in the bullet in flight to the extent the bullet begins a non-linear helical spiral in flight or its flight path goes off on a non-linear tangent from the line of flight.

Exceeding the RPM Threshold does not adversely affect bullet stability except in extreme cases. Most often, even though over the RPM threshold and accuracy are decreasing both in group size increase and in non-linear group expansion as range increases, the bullet will still be stable in flight.

It is best noted when working up a load as velocity increases flyers begin to happen. Then as velocity is further increased the total group size increases sometimes to the point some bullets fly so far off they miss the target. A further indication the cast bullets at or over the RPM threshold is (or some of them in a load that is on the edge of the RPM threshold) the non linear dispersion of the group size as range increases.

Let us keep in mind the RPM threshold most often falls in the 120,000 to 140,000 RPM range with regular lube groove cast bullets. Exactly where the RPM threshold will be in fps depends on numerous factors; alloy, bullet design, fit, sizing, lube, GC’d and seated square, powder burning rate and the length of the barrel, etc. The RPM threshold may be lower than 120,000 RPM by careless casting and loading techniques or when using very soft alloys with very fast burning powders. Conversely, the RPM threshold can be above 140,000 by careful casting and bullet selection and preparation along with careful accuracy enhancing loading techniques, especially those for cast bullets at high velocity such as using slow burning powders that ignite easily and burn efficiently at lower pressures. The trick is to get the cast bullet to exit the muzzle as balanced as possible with as little deformation to it during acceleration. The more balanced the bullet is and the closer the axis of rotation coincides with the center of mass on exit from the muzzle and during flight the more accurate the bullet will be and thus, the higher the RPM threshold will be.

The RPM threshold is not a set “limit” of RPM or velocity. Best accuracy will be just under the RPM threshold or lower. Useable accuracy can be had above the RPM threshold if the ranges are not long and the accuracy requirement is not small. Keeping .223 cast bullets on a silhouette target out to 200 yards for example or keeping hunting cast bullet accuracy at say 4 moa if the max range to be used is 50 – 100 yards.

Again; the RPM threshold will generally be found between 120,000 to 140,000 RPM with regular commercial cast bullet designs and loading techniques most cast bullet shooters use.

In the chart below I’ve computed the fps for various common barrel twists for 120,000 and 140,000 RPM. For other twists in between anyone shouldn’t find it too difficult to interpolate. These fps figures should give you an idea in what fps range your loads, as you work them up, will probably bump into the RPM threshold and when accuracy will probably begin to deteriorate. Some pundits will criticize this chart saying they, or someone else, gets accuracy above the figures in the chart. For those who understand how to push the RPM threshold up with higher velocity cast bullet loads that can indeed be the case. However, as mentioned, the chart is for the majority of cast bullet shooters who do not care to push the RPM threshold up but simply want to understand where and why accuracy will probably deteriorate with their regular cast bullet loads. This chart was done for them.

RPM……….120,000……….140,000

Twist……….FPS…………..FPS

7”…………1166…………..1361

8”…………1333…………..1555

9”…………1500…………..1750

10”………...1666…………..1944

11”………...1833…………..2139

12”…………2000………….2333

14”…………2333………….2722

16”…………2666………….3111

18”………….3000…………3500

Thus those RPM threshold figures are not hard and fast as some things like a too soft alloy or too fast a powder can lower the threshold. Conversely, other things like a harder alloy or a slow burning powder can raise the threshold. However the RPM threshold is pretty consistent when we use cast bullets of designs that are readily available through commercial venders and are what most cast bullet shooters use. It is also these same designs that commercial bullet casters offer. Given a medium or slow burning powder we know that accuracy improves as the consistency of the internal ballistics improves. At a certain velocity accuracy begins to deteriorate. Since the RPM of a bullet is directly related to the twist (or show fast the bullet spins) of the barrel and the velocity at a certain point the RPM creating higher centrifugal force) overcomes the rotational stability of the bullet and accuracy decreases. The RPM threshold can be lower or the RPM threshold can be crossed into higher velocities if we use specialized cast bullet designs or tweak the loads in other ways. But for the most of us who use regular cast bullets the RPM threshold appears to be real and we need to understand it.

For a bullet to fly straight the center of form should coincide with the center of gravity and the center of spin must then coincide as closely to those as possible. When these centers do not coincide we have an unbalanced bullet that does not fly straight. A bullet thus imbalanced may wobble, it may yaw and/or its flight path may corkscrew around the intended flight path. The degree of these imbalances directly affects the accuracy or the ability to hit the same spot on the target. In basic terms an imbalanced bullet does not fly straight.

Can we demonstrate an increase in RPM above a certain threshold overcomes the rotational stability and decreases accuracy? Can we measure if and when bullets become more imbalanced? Will there be a direct correlation between measurements of imbalance and inaccuracy? All of these are good questions and the answer to all of them is yes. Let me explain but first I will describe the 3 test rifles.

All three rifles are chambered in .308 Winchester. All three are accurate with jacketed bullets and cast bullets. All three have free floated barrels. The three rifles have three different twists. The three test rifles used are; the 10” twist rifle is a M1909 Argentine Mauser with a 24” heavy sporter barrel. It has a Timny trigger set at 2 lbs. It has a 10X Weaver MicroTrac scope on it. This rifle is capable of consistent

MOA accuracy with quality bullets. The 12” twist rifle is a M70 varmint rifle with heavy 26” barrel. The trigger is also set at 2 lbs. It has a 3x12 Redfield Ultimate scope on it. This M70 is capable of ½ MOA with match bullets. The 14” twist rifle is a M98 Mauser with a 27.5 barrel of Palma taper and weight. It too has a 2 lb trigger. This rifle has a 16X Weaver T16 on top. It is also capable of ½ MOA with match bullets.

What about the test loads? Well I will use the exact same loads in all three rifles. I will compare the accuracy of each rifle unto itself. In other words each rifle and it’s bullets flight will tell us when that rifles accuracy begins to deteriorate. The loads used in all three rifles will be the same and it is then when accuracy deteriorates in one rifle the RPM of that rifle with that load is comparable to the RPM of the same load in the other rifles.

Now to explain how we can measure if and when a bullet becomes imbalanced. I will use an Oehler M43 Personal Ballistics Laboratory to provide these measurements. The M43 will tell us the Time Of Flight and give us the Ballistic Coefficient of the bullet by measuring the muzzle velocity and the down range velocity. Along with the TOF and BC it will provide Standard Deviations and Extreme Spreads for these. A bullet that is not flying straight (imbalanced and inaccurate) will slow down quicker, have a lower BC and the SD/ES at the down range screens will be greater than that of a bullet that is flying straight (balanced and accurate). Thus if we have a bullet that is shooting accurately and as we increase velocity, with the attendant increase in RPM,

the accuracy decreases it tells us the increased centrifugal force of the higher RPM has overcome the rotational stability of the bullet and decreasing accuracy is the result. The M43 will also measure the chamber pressure of each round fired so we may compare how pressure may be affecting the bullet.

Now wait a minute you say, by increasing velocity we are increasing acceleration and the bullet is deforming in the bore through obturation and set back. That is the reason for the poor accuracy. Well that sometimes may be the case. However remember, we are using the same loads in each rifle so if the 10” twist rifle becomes inaccurate before the 12 and 14” twist rifles with the same load then we can assume it is the increased RPM of the 10” twist barrel is the culprit. Then if the 12” twist rifle also becomes inaccurate before the 14” twist rifle, all with the same load, then we have confirmed it is the increased RPM that is causing the inaccuracies.

To demonstrate the validity of these test methods a simple test was conducted with the 10” twist rifle. The M43 was set up with testing done at 100 yards. M118 Special Ball was used for the test. Now I think we can agree the 174 gr M118 bullet is not going to suffer any set back, bending, torque twisting or undue obturation during acceleration. At any rate, the test here is between regular M118 bullets and those I purposely unbalanced. If the regular M118 bullet suffers any of the mentioned deformations then the unbalanced M118 bullets would suffer the same deformations. So what we are testing is what the different effect of RPM will be on the balanced and unbalanced bullets.

This lot of M118 ammo, while 1.1 – 1.2 moa accurate in 12” and 14” twist barrels has not been much better than 2 moa in 10” twist barrels including M24 sniper rifles. And so it was with the M1909 with 10” twist. A ten shot string of regular M118 bullets was fired and they grouped right at 2 MOA. Then the ten shot string was then fired with the same lot (actually with the other 10 rounds out of the same 20 round box) of M118 that I had drilled a hole in the side to unbalance the bullet. I used a #31 drill and drilled the hole .06” deep removing 1.7 gr of the bullet in the side right in front of the case mouth. The M43 showed that the unbalanced bullets, when compared to the regular M118, averaged 5 fps faster MV, had a slower TOF, down range velocity was slower and had a lower BC. This is ample evidence the unbalanced bullets were not as stable in flight as the regular M118. The clincher was the group. The regular M118 grouped 2 MOA and the unbalanced M118 grouped into 6 MOA. Ample evidence of how the centrifugal force of the RPM affects the accuracy of unbalanced bullets. A picture of the two groups is attached.

How does this apply to cast bullets? Well most all cast bullets we cast are not perfectly round nor does the center of gravity coincide with the center of form. How much the cast bullet obturates, sets back, the nose bends to one side or the lube grooves collapse during acceleration depends on the hardness of the alloy and the fit to the throat. We should realize our beloved cast bullets for the most part are fairly unbalanced once they leave the muzzle. However with a normal alloy like WWS or #2 alloy GC’d cast bullets seem to withstand all this fairly well and given a reasonable fit to the throat they have good rotational stability and shoot accurately up to a certain point. It is at that point the centrifugal force of the RPM overcomes the rotational stability and the bullet shoots less accurately.

I intend to initially test two bullets; 311291 and 311466. Both will be cast from Lyman 2 cavity moulds. Alloy will be air cooled and the bullets have a BHN of 15-18. The gas checks will be Hornady’s and are seated with the Lyman 450 GC seater prior to sizing. The lube will be Javelina. Bullets will be sized in the Lyman 450 using a .311 H die. Powder will be H4895 with a ½ gr Dacron filler. Loads will work up in one gr increments from 26 to 36 grains. Cases are LC with the necks inside reamed with a Lee Target Loader for concentricity. All cases have been fire formed in their respective rifle and neck sized with a Forster/Bonanza Benchrest NS die. A Lyman .31 M die is used to expand the necks and flair the case mouths. The bullets are seated to just slightly engrave on the lands. Additional loads tested will be with two slow burning powders; RL19 and H4831SC.

Expected test velocities are expected to run from 1700 fps up through 2600 fps. Approximate RPM range of those velocities with each twist are:

10” twist; 122,500 – 187,000 RPM

12” twist; 102,000 – 156,000 RPM

14” twist: 87,500 - 134,000 RPM

When consistent high velocity loads (internally ballistic uniformity) are found additional tests will be conducted with the 10” twist rifle as it has the highest RPM potential. Those additional tests will be with different lubes (Lars), with the bullets water quenched out of the mould, will bullets cast of linotype and with bullets of various sizing (.311, .310, .309 and .308). Of course only one change will be tested at a time in an effort to see if the HV loads can be “tweaked”. I will even, to appease Bass, test with different barrel pressure.

Tests with the cast bullets will begin soon. Stay tuned for Chapter Two.

LMG