Experiments with Bismuth

Abstract:

Beginning 1 July 2019, the State of California will require the use of lead-free projectiles while taking all game and non-game animals. The availability of lead-free projectiles has been problematic since first requiring their use within the designated Condor range on 1 July 2008. For many older weapons or unusual calibers, California routinely exceed the total national output of lead-free ammunition, causing many to retire firearms or simply leaving the shooting sports altogether.

Those choosing to hunt with traditional muzzleloader using patched round ball were particularly hard hit by this requirement as there was only one approved lead-free round ball on the market. Those balls were manufactured by ITX using a proprietary powdered metal material that were expensive and only offered in 3 sizes.

Recently, RotoMetals of San Leandro CA began marketing a lead-free bullet casting alloy consisting of 88% bismuth and 12% tin that is on CA Department of Fish Wildlife's approved list. It is primarily marketed towards those who choose to cast their own conical bullets for either hunting or silhouette shooting. Since the product comes in 1 pound bars, it was thought that it would lend itself well for casting round balls for traditional muzzleloaders.

The research presented here investigates the viability of the RotoMetal alloy as a green substitute for hand cast .54 caliber lead round balls while hunting.

Preparation:

Measured diameter inches	Measure weight in Grains
0.534	191
0.5345	190.4
0.5355	190
0.535	191
0.534	191
0.5335	190.2
0.534	190.8
0.535	190.3
0.534	190.3
0.5335	190.2
0.534	190.5
0.533	190.7
0.533	190.3
0.5335	190.1
0.533	190.8
0.5345	190.6
0.5345	190.6
0.5335	190.4
0.5335	190.3
0.5345	191
0.5335	190.1
0.5335	190.8
0.534	190.3
0.534	190.3
0.5335	190.2

In discussion with RotoMetal, it was revealed that the alloy expanded slightly during the post casting cooling, but to what degree was unknown. Because both bismuth and tin have lower densities than lead, the cast round ball was expected to be lighter, but again, to what degree was unknown.

Because of these unknowns a Lee two-cavity .530 bullet mold was chosen in the hopes that the final diameter was equal to or less than .535".

A new RCBS cast iron metal melting pot was purchased as was a new pour ladle. Three pounds of the alloy was placed in the pot and melted at around 375 F. Pouring commenced when the temperature of the molten metal reached 500 F.

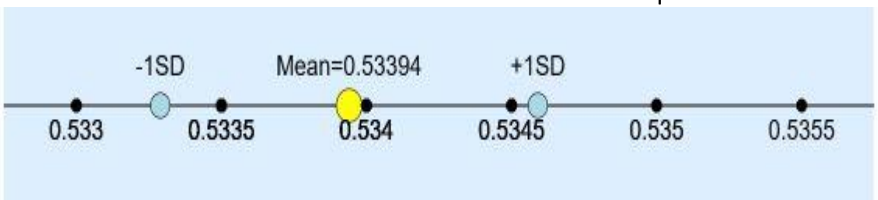
Casting:

Three pounds of the alloy yielded 99 poured balls. A sample population of 25 balls were selected at random, weighed and diameter measured with the following results.
The average/mean bullet diameter was .53394 inches. Maximum diameter was .5355 inches and the minimum .5330 inches.

Using the sample standard deviation formula;

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

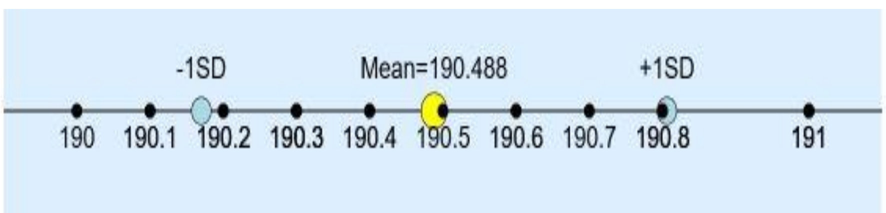
The standard deviation was calculated as 0.00065" and plotted as follows.



As shown, the maximum deviation was +/- 0.00065 inches of the average diameter. Three cast balls were outside one standard deviation.

The average/mean weight of the cast balls was 190.488 grains. The maximum 191.0 grains and the minimum was 190.0

Once again using the sample population formula, the standard deviation was calculated as 0.31796 grains and plotted as follows



Four cast balls were outside one standard deviation.

Using the mean bullet diameter of .53394, we can calculate the expansion of the bismuth/tin alloy

$X = (100\% * .53394")/.530"$ or X= 100.74%

Sample data indicates that the bismuth/tin alloy cast in a .530 mold only expanded 0.74% yielding an average diameter of .53394". This is an acceptable result as it is 1/1000th of an inch under the .535 target diameter.

A standard .530" lead ball weighs 225 grains. Our mean/average weight of the cast bismuth/tin alloy was 190.488 grains. We can calculate the weight loss between alloys as

X = (100%*190.488gr)/225gr or X = 84.66% grains.

Sample data indicates that given equal volumes, the RotoMetal weighed 14.96% less than lead.

Cost comparisons for .530” round ball

Speer Swaged lead round balls, 100 count	$14.85 or $0.15 per ball
Hornady lead round balls, 100 count	$13.73 or $0.13 per ball
ITX lead free ball, 10 count	$11.99 or $1.19 per ball
RotoMetals alloy $15.59 per lb, 3 lbs , 99 count	$46.77 or $0.47 per ball

Range Test:

The firearm used to test the alloy round ball is a flintlock with a .54 caliber Rice swamped barrel, 38 inches in length with 1:66 rifling. Past experience indicates that the most accurate powder/patch/ball combination is 85 grains of MZ Black Powder, a .535” diameter lead ball and a 0.022” cotton duck patch lubricated with Jojoba oil.

Figure 1

The rifle had previously been sighted in at 100 yards with the above powder/patch/ball combination.   Each shot was taken at the same point of aim without sight adjustment or use of “Kentucky windage”. Targets are 12” diameter splatter type targets. Figure 1 shows results of a firing string at 50 yards. Bismuth/tin balls on the lower target and lead ball balls on the upper.

Four shots were taken with lead and grouped around 2”.

Six shots were taken with bismuth and the results mixed. The three in the white were the first three shots and next three grouped quite well, again around 2”.

Figure 2 shows a seven shot string of bismuth balls only on the lower target. There's approximately a 13" spread with one outlier near the 4 o'clock position on upper target.

The intent was to shoot ten each of bismuth and lead, on the lower and upper target, respectively. However the eighth shot was "dry balled", effectively ending this portion of the experiment.

Figure 2

Hardness:

It is worth noting that lead has a Brinell hardness of 5 (quite soft) while the RotoMetals alloy has a reported Brinell hardness of 19.3 (quite hard). This presents the shooter with a dilemma when trying to extract a "dryball" or unfired charge. The standard ramrod screw extractor is very difficult to get started in the bismuth/tin alloy and will only enter the ball a short way using hand pressure. Attempts to use the screw adaptor were not successful, as screw extractor, coupled with the brittleness of bismuth simply cause the ball to fracture, leaving it stuck. Attempts to use a CO2 and compressed air to eject the ball were unsuccessful due to the ball obstructing the touchhole. The barrel breech had to be removed to remove the" dry ball".

Figure 3 shows two balls. The left ball was recovered from the 100 yard dirt backstop and the right ball is the "dry ball" and the resulting metal fracture caused by the attempt to remove using the screw extractor.

Figure 3

Both balls showed positive contact with the rifling.

Conclusion:

This initial experiment indicates that the RotoMetals alloy has potential as green substitute for lead balls. It is felt that experimenting the powder/patch combination would help improve the accuracy. Although the cost per ball is more than three times that Speer swaged lead balls, it is less than half the cost of the ITX round ball.

The hardness is problematic. The balls show almost zero malleability. Although it didn’t damage the rifling, the lack of expansion from the ball recovered from the berm may inhibit energy transfer while hunting, resulting in lost game. Shot placement will be critical.

In the event of a “dryball” in a field condition, the hunt will be effectively over. It’s unlikely that the ball could be removed in the field.