Using Statistical Analysis to Determine Quality Control and Accuracy of Product Specifications

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Introduction:

This is a report on a study conducted for IPFW's fall of 2016 IET 205 course. The study was to determine if a certain product line of ammunition performed similarly to manufacturer specifications. The process done to collect data was an observational study. In order to lower bias two types of firearms were used a Ruger 10/22 (semi-automatic, straight blowback design) and a Savage mkII (standard bolt action, front locking-lug design). No blinding was used to during the courses of data collection and evaluating. Data was collected using a chronograph. After the data was collected, Microsoft Excel was used for graphing and evaluation. Conclusions were drawn by comparing collected data to the manufacturer's specifications.

Rationale and Explanation

For the project, 150 rounds (three boxes) of "bargain" .22l.r. ammunition were used to see if the bullet masses and muzzle velocities were consistent with the manufacturer's specifications. Data was collected for the velocities of 113 rounds and the component weights of a sample of 15.

The ammunition chosen was manufactured by Geco-munitions, with a product name ".22 l.r. Rifle". The reason these rounds were chosen is simple: they were the cheapest ammunition available without pre-ordering. It is a commonly accepted assumption in the firearm industry that factory-loaded ammunition will perform equivalent to its price--i.e. cheap ammunition will perform poorly, and an expensive ammunition will perform higher than average ammunition.

Due to a nation-wide shortage of .22 (bullet diameter of .23) ammunition at the time--including .22 short, .22 l.r., and .22 Winchester Magnum—it was very difficult to procure high quality ammunition without pre-order. An example of what would be considered "good quality" ammunition would be CCI products such as *Stinger*, *Maxi-Mag*, or *Blazer*. These ammunitions are commonly accepted to hold consistent accuracy, velocity, and muzzle energy.

To determine if the ammunition is a “good” round, the determining factor would be the difference between the average of collected data and the manufacturer’s specifications. The “cut-off” was set to be one standard deviation, meaning that if the manufacturer's specification is within one standard deviation from the mean of collected data, it was considered a “good ammunition”. All testing was done with a standard rifle with an 18 inch barrel, to get a general understanding as to how the round would perform for the average consumer.

Methodology

The methods used to collect data for the ammunition were fairly standard procedures in the firearms world. It is common practice to measure the velocity of a round, the mass of the bullet--or the weight of the projectile--,the mass of the charge--or the weight of gunpowder used to propel the projectile--,and the consistency of the primer--in this instance, since the cartridge being tested is a rimfire, the primer is in the rim of the cartridge, meaning that it cannot be deprimed, so the primer and brass were weighed at the same time for consistency.

The foremost way to collect data in terms of velocity is a chronograph. The Chronograph used to measure the velocity of the tested rounds was a *PACT MK IV Championship Timer & Chronograph.* Being a well respected brand, the chronograph is very accurate, and only proves to be problematic in low-light conditions.

To measure the mass of the bullet, charge, and case & primer, a *Frankford Arsenal Reloading Tools DS-750 Digital Scale* was used. This scale is accurate to one-tenth of a grain of black powder(gn.) or five-ten thousandths of an ounce(oz.).

Once all of the measurements were taken, they were graphically analyzed, and compared to the factory advertised information.

Figure 1. Frankford Arsenal Reloading Tools, DS-750 Digital Scale With 50.000g calibration weight. Powder cup right of scale.

Apparatus:

Figure 2, Testing Apparatus. The Firearm on the left is the Ruger 10/22, the firearm on the right is a Savage mkII with a Barska 8-32x50mm Rangefinding graph scope and bipod. The PACT chronograph is set up twelve feet from the muzzle of the barrel, and the chronograph display and timer is on the table communicating via a wired connection.

Collected Data:

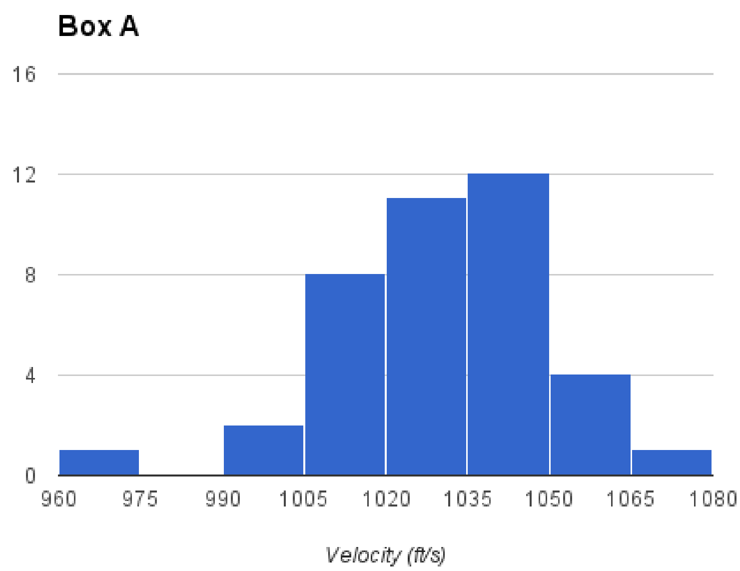

Figure 3, Box A. Histogram representing the data collected with the first box of ammunition tested. This box was fired with the Savage mkII and had a mean velocity of 1029.78 feet-per-second, and a standard deviation of 19.89 feet-per-second.

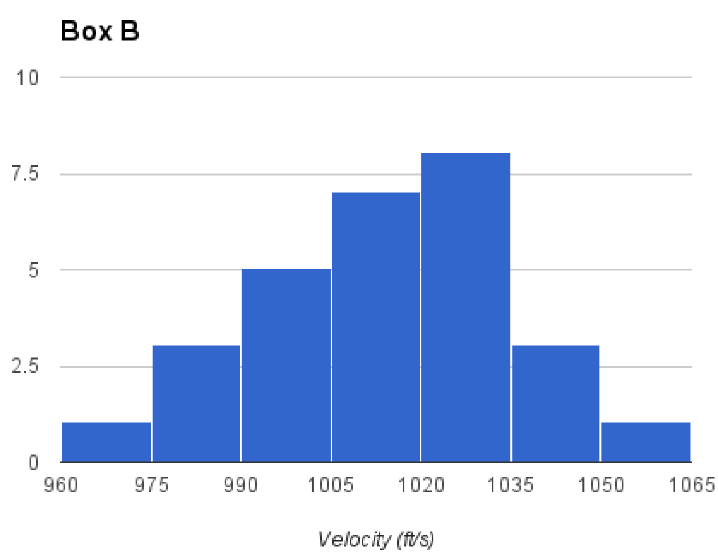

Figure 4, Box B. Histogram representing the data collected with the second box of ammunition tested. This box was fired with the Savage mkII and had a mean velocity of 1013.09 feet-per-second, and a standard deviation of 21.07 feet-per-second.

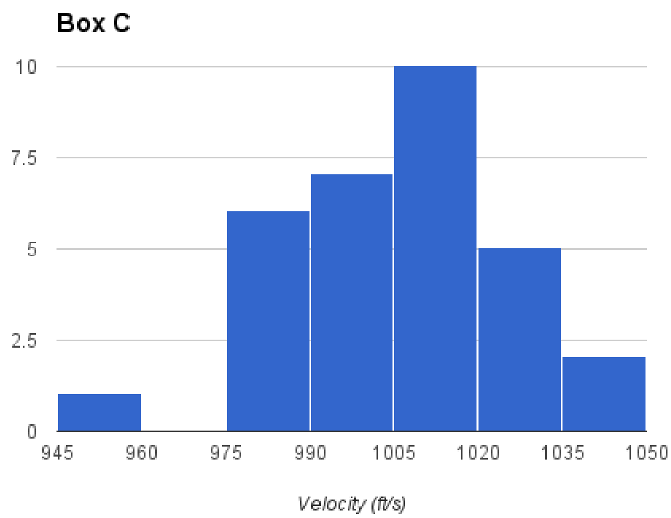

Figure 5, Box C. Histogram representing the data collected with the third box of ammunition tested. This box was fired with a Ruger 10/22 and had a mean velocity of 1005.59 feet-per-second, and a standard deviation of 18.09 feet-per-second.

Comparison:

In comparing the three data sets they all have outliers and in almost every case are not able to hit the manufacture specified value of 1080 ft/s within two standard deviations. There are many possible explanations as to why this could be. For example, a source of error could be related to atmospheric conditions—tests were conducted outside where barometric pressure and winds could have affected performance. Another potential source of error could have been the angle at which the projectile passed through the chronograph—minimizing this source of error would require a very precise apparatus. All of these factors above or a combination thereof could be possible sources of error that could have skewed the results. The sources of error were minimized to the best of the research team's ability, with the resources available at the time of the procedure.

The factory specifications provided by Geco-munition are shown in Figure 6.

Factory Specifications
40 Grain
Muzzle Velocity 1080 ft./s
Muzzle energy 104 ft.*lb

Figure 6, Manufacturer's Product Specifications

Raw Data:

Box: A

Savage MKII

#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)
1	xxx	11	1018.4	21	1049.8	31	1039.2	41	
2	1064.6	12	1020.5	22	1031	32	1048	42	
3		13	xxx	23	1018.9	33	1050.9	43	1046.8
4	993.5	14	1020.1	24	1019.1	34	1032.5	44	1024
5	1036.6	15	1040.8	25	xxx	35	1047.9	45	1035.5
6	1010.4	16	1043.7	26	1022.3	36	1012	46	1010.7
7	1028.9	17	1026.1	27		37	xxx	47	1015.6
8	965.8	18	998.6	28	1041.8	38	1042	48	
9	1053.3	19	1048.2	29	1024.8	39	1052	49	xxx
10	1021.7	20	1065.1	30	1015.4	40	1024.8	50	

mean: 1029.7769
SD: 19.890932

	Mass			
Number	Total Mass (grains)	Bullet (grains)	Powder (grains)	Cartridge & Primer (grains)
1	53.1	41.3	1.4	10.4
13	53	41.4	1.3	10.3
25	52.9	41.3	1.3	10.3
37	52.9	41.4	1.3	10.2
49	52.9	41.3	1.3	10.3

Figure 7, Raw Data: Box A. provided is the Raw Data for Box A.

Box: B

Savage MKII

#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)
1	xxx	11	1028.1	21		31		41	1042.6
2	980.3	12	1013.5	22		32		42	1027.2
3	991	13	xxx	23		33	1009.5	43	1006.1
4	1043.7	14	1016.6	24	982.1	34	1020	44	1036.9
5	966.6	15	1014.5	25	xxx	35	996.6	45	1000
6	1027.4	16	996.5	26	1058.2	36	985.3	46	1025.2
7		17		27	1002.2	37	xxx	47	1022.7
8		18		28		38		48	1026.8
9	1011.6	19	1012.2	29		39		49	xxx
10		20		30		40		50	1023.2

mean: 1013.0928
SD: 21.072360

	Mass			
Number	Total Mass (grains)	Bullet (grains)	Powder (grains)	Cartridge & Primer (grains)
1	52.8	41.3	1.2	10.3
13	53	41.4	1.3	10.3
25	52.8	41.3	1.2	10.3
37	53	41.4	1.3	10.3
49	52.9	41.4	1.2	10.3

Figure 8, Raw Data: Box B. provided is the Raw Data For Box B

Box: C

Ruger 10/22

#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)	#	Velocity (ft/s)
1	xxx	11		21		31	997.5	41	959.3
2	1035.4	12		22		32	1000.7	42	1011.8
3	1007.4	13	xxx	23	1037.6	33	1030.7	43	1012.2
4	1020.1	14		24	987.4	34	1003.8	44	1022.3
5		15		25	xxx	35	998.6	45	1017.2
6		16		26	998.8	36	988.9	46	1005.2
7	1006.6	17		27	988.7	37	xxx	47	1030.6
8	1016.2	18		28	977.7	38	996.3	48	1014.5
9		19		29	1015.8	39	980.8	49	xxx
10	981.8	20		30	1009.3	40	997.5	50	1022.7

mean 1005.5935

SD 18.090862

Number	Mass: Total Mass (grains)	Bullet (grains)	Powder (grains)	Cartridge & Primer (grains)
1	52.8	41.3	1.2	10.3
13	53	41.4	1.3	10.3
25	52.8	41.3	1.2	10.3
37	53	41.4	1.3	10.3
49	52.9	41.4	1.2	10.3

Figure 9. Raw Data:Box C. Provided is the Raw Data For Box C.

Comparison of Masses

Below is the collected data for the masses of the bullets, powder, and casings/primer. 15 rounds (5 from each box) were selected, disassembled, and weighed to determine the mass of the components, .

Number	Total Mass (grains)	Bullet (grains)	Powder (grains)	Cartridge & Primer (grains)
A1	**53.1**	**41.3**	**1.4**	**10.4**
A13	**53**	**41.4**	**1.3**	**10.3**
A25	**52.9**	**41.3**	**1.3**	**10.3**
A37	**52.9**	**41.4**	**1.3**	**10.2**
A49	**52.9**	**41.3**	**1.3**	**10.3**
B1	**52.8**	**41.3**	**1.2**	**10.3**
B13	**53**	**41.4**	**1.3**	**10.3**

B25	**52.8**	**41.3**	**1.2**	**10.3**
B37	**53**	**41.4**	**1.3**	**10.3**
B49	**52.9**	**41.4**	**1.2**	**10.3**
C1	**52.8**	**41.3**	**1.2**	**10.3**
C13	**53**	**41.4**	**1.3**	**10.3**
C25	**52.8**	**41.3**	**1.2**	**10.3**
C37	**53**	**41.4**	**1.3**	**10.3**
C49	**52.9**	**41.4**	**1.2**	**10.3**

Figure 10.

The factory specified mass and the average masses for each box are listed below, along with the factory specified velocity and average velocities for each box.

	muzzle velocity (fps)	bullet mass (gr)
Box A	1029.78	41.34
Box B	1013.093	41.36
Box C	1005.59	41.36
Total	1017.36	41.35
Spec	1083.00	40.00

Figure 10.

The relationship between these quantities is expressed by the scatterplot below, showing a strong negative correlation between mass and velocity. This makes sense, because $f = \frac{1}{2}mv^2$, therefore if the powder charge (force) is held constant, the velocity should vary inversely proportional to the mass.

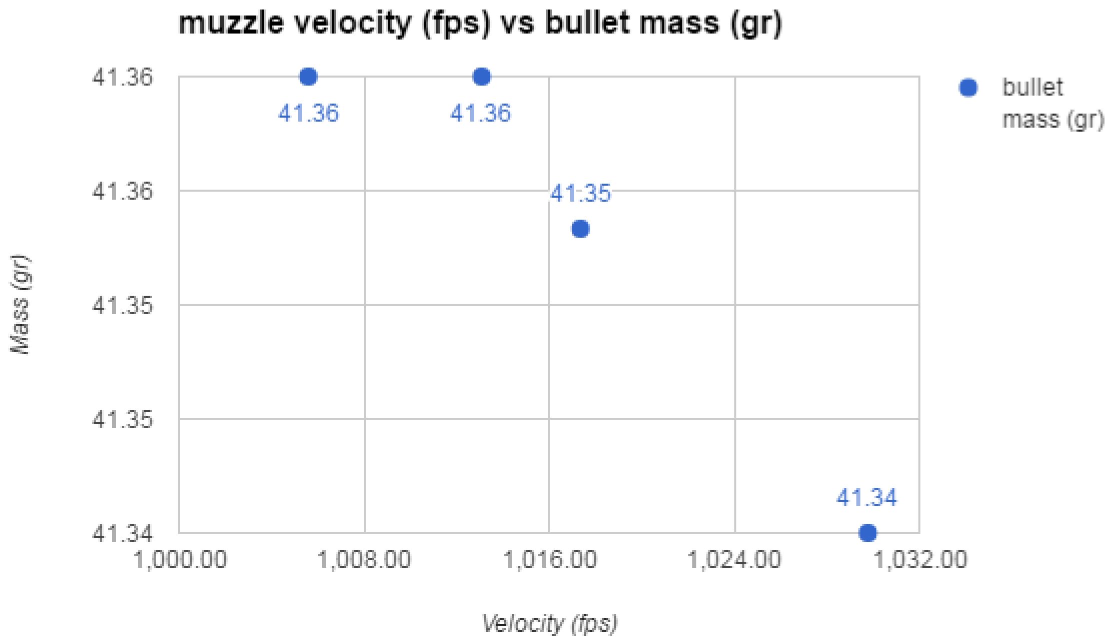

Figure 11. Average Bullet Mass over Average Velocity

As shown in figure 12, the velocity and bullet mass are related, as bullet mass increases, velocity decreases. The negative influence of increasing projectile mass would compensate for the higher factory specified velocity, considering the specified mass is 40 grains.

This points to speculation that the decreased velocities in tested ammunition was a result of bad quality control of the projectiles themselves.

Findings and Evaluation

The results of the tests conducted conflicted with the information provided by the manufacturer. The muzzle velocity stated by the manufacturer—1083 ft/s—is not close to any data set recorded in the tests. The closest set of recorded data is the data for box A. The advertised velocity of 1083 ft/s is 2.67 standard deviations from the mean velocity of 1029.78 ft/s for the box.

With an overall average muzzle velocity of 1017.36 ft/s, and an average bullet weight of 41.35 grains, the resulting muzzle energy would be 95 ft*lbs. This is 9 ft*lbs lower than the manufacturer's specification of 104 ft*lbs. With the 1.35 grain variation from the specified bullet weight, there was no compensation in powder charge, to accommodate for the heavier bullets. This means that since the average mass of the bullets was higher than the specified 40 grain production mass, the energy produced was lower because the powder charge remained relatively unchanged.

Overall, the performance out of the Geco-munitions .22 l.r. Rifle ammunition was less than adequate, when the assumed values were based on the factory specifications. Due to the fact that the ammunition performed with lower velocities, higher bullet weights, and lower energy than specified, the results showed that a change in quality control or manufacturer specifications was required. This conclusion is attributed to the difference in mass shown in the projectiles, and variations on powder charge

Report Conclusion: Recommendation to the manufacturer

The Report concluded with a recommendation to the manufacturer. The suggested corrective action was an increase of quality control for the production of bullets (the projectile component of ammunition) to ensure a bullet mass of 40.0± 0.1gn., which would result in muzzle velocities closer to the manufacturer's specification. This recommendation would also increase consistency, resulting in less deviation.

References

Staller, S., Werling, M., Jimenez, E., Hauter, M., & Rensberger, J. (2016). USING STATISTICS TO STUDY BULLET PERFORMANCE (Rep.). Fort Wayne, IN: Indiana University-Purdue University, Fort Wayne.