Bullet Seating Force & Effect on Interior Ballistics Performance

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Abstract

The push force required to seat a projectile in the mouth of a cartridge case is thought to be related to the shot start force required to release the projectile to start its travel down bore. Annealing the case mouth is thought to reduce muzzle velocity variability by making the bullet release from the case mouth happen at lower and more consistent pressures. On-hand resources were employed to measure the peak seating force in twenty-five samples of 25 caliber and 30 caliber cartridge cases. Case and bullet dimensions were taken and recorded prior to starting the test. Acquired data was then used as inputs into a lumped parameter interior ballistics code to assess the effect of shot start variation on muzzle velocity consistency.

Background

The "shot start pressure" of a cartridge can affect the interior ballistic performance of an individual cartridge. Closed form estimates of shot start pressure using a "strength of materials" approach and typical static coefficient of friction yielded unrealistically high values based on known interior ballistic performance of small caliber ammunition. Measurements and simulations of small caliber interior ballistic systems for non-military application indicate <u>the propellant in the cartridge case doesn't start burning until the bullet starts engraving in the forcing cone of the barrel; the projectile is forced out of the case mouth by the physical translation of the propellant bed relative to the cartridge case brought about by primer ignition</u>. Thus, the "shot start pressure" required to move the bullet from the case neck is smaller than peak engraving pressure by an order of magnitude, or perhaps more.

Equipment

Cartridge Cases & Projectiles

50 cartridge cases of for 25-05 and 30-06 were used for this experiment, along with bullets appropriate for each cartridge. The 30-06 cartridge cases were Lake City (LC) 1972 production. The 30 caliber bullets used were Hornady 220g ELD-X's, lot number 2151776. The 25-06 cartridge cases were converted from LC 30-06 cartridge cases manufactured in 1966, and the bullets used were Speer Item 1410, 120g Boattail spire points, of an age that the lot number is obscured by an SKU sticker on the package and the lot number cannot be determined.

Bullet Press and Press Force Measurement

A simple press was constructed of dimensional lumber and a few other bits of hardware to allow measurement of bullet push force without the compound leverage found in typical reloading presses. A photograph of the press on the test bench is shown below in Figure 1. The lever arm 2x4 was shortened and the cut off end reattached to the lever because a 4-foot length was too heavy (the weight of the full-length lumber lever arm would press the bullet a fair distance into the case neck with no additional force applied), and the shortened lever arm required force high enough that the 1 kg limit of the Cen-Tech scale (item 60332) acquired from Harbor Freight was exceeded. The scale was attached to the lever arm by masking tape applied to its base; the scale is seen as the black object at the top of the lever in Figure 1.

Figure 1: Bullet Press Assembled on Test Bench

Procedure

The base 2x4 had a ½" diameter hole drilled into the top surface to restrain the base of the cartridge case. The hole was drilled at an angle to the top surface of the 2x4 to provide a closer to perpendicular force applied to the nose of the projectile during the pressing operation. Figure 2 shows a close-up of a 30 caliber bullet being pressed into a 30-06 cartridge case. Since the 25-06 cartridge is derived from the 30-06 case, only one half-inch diameter hole was needed in the base 2x4.

Figure 2: Pressing a Projectile Into the Case Neck

Figure *3* shows my finger applying force to the load table of the scale, along with the load measurement displayed. Load was applied to the load table of the scale in a slowly increasing manner, and the maximum load, rounded to the nearest 10gm was recorded for each bullet that was properly pressed into a case neck. In some instances, bullets were pressed into the case necks at an angle resulting in an assembled cartridge which could not be chambered. The data was not used for instances where the bullets were not properly pressed into the case necks.

Figure 3: Push Force Measurement

Data & Results

Cartridge cases were serialized, and neck inside diameters (ID) and outside diameters (OD) were recorded in a spreadsheet. Figure 4 shows the case mouth inside diameter vs. case mouth wall thickness for a sample of fifty-eight (58) 25-06 cartridge cases.

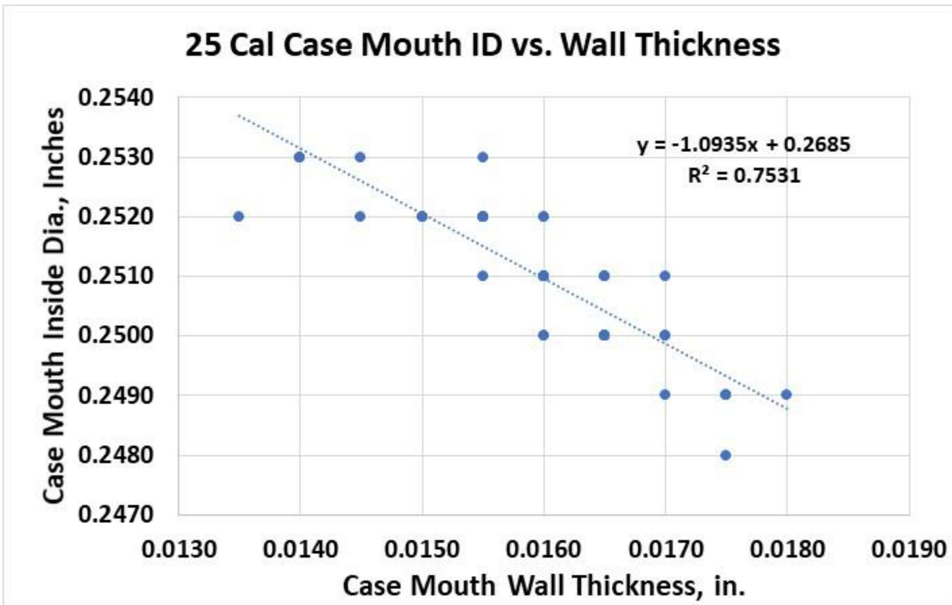

Figure 4: 25 Caliber Case Mouth Dia. & Wall Thickness

The same data collection was conducted for the 30-06 cartridge cases; Figure 5 shows the case mouth wall thickness vs. case mouth inside diameter for a sample of 63 cartridge cases.

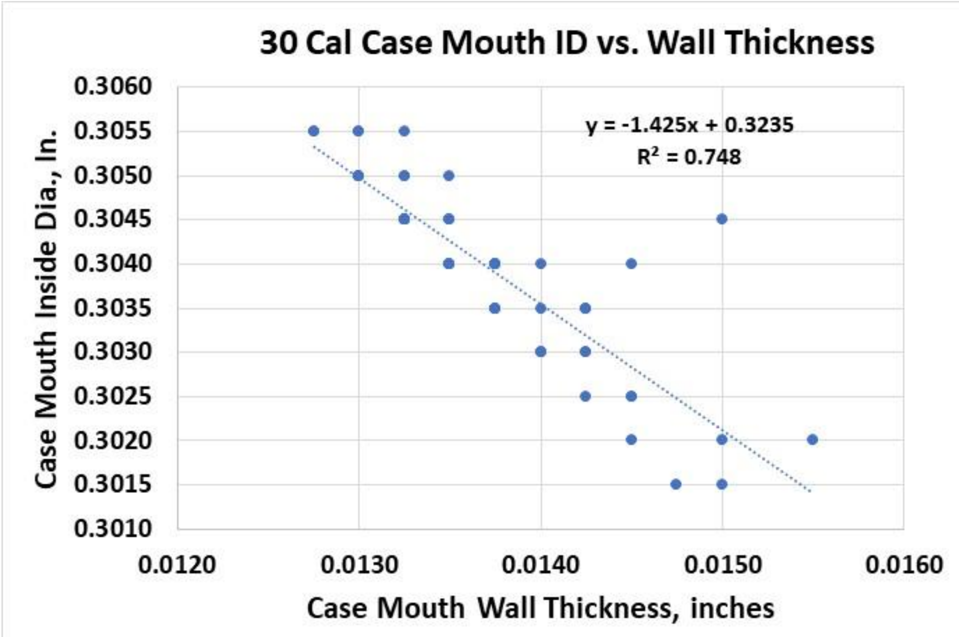

Figure 5: 30 Caliber Case Mouth Dia. & Wall Thickness

Figure *6* shows the maximum push force, converted to base pressure as a function of push test sample number for the 25 caliber and 30 caliber bullets and cases.

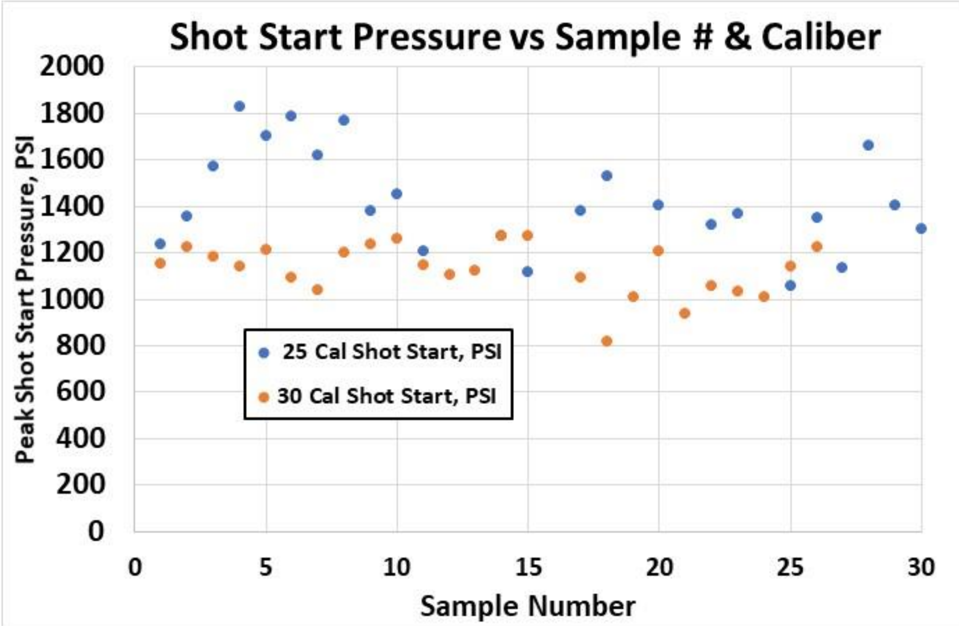

Figure 6: Shot Start Pressure vs. Sample No. & Caliber

Interestingly, the correlation coefficients between peak push force and the interference between the projectile and the case mouth are very small, (-1.0 indicating inverse correlation, 0 indicating random, and 1.0 signifying perfect correlation) suggesting the push force (as well as resulting shot start pressure) is the result of essentially random factors. Table 1 lists the correlation coefficient between the amount of interference between the case neck and the bullet and the measured peak push force.

	Correlation Coeff.
25 Caliber	0.104
30 Caliber	0.052

Table 1: Correlation Between Case Neck – Bullet Interference & Peak Push Force

The lack of correlation between the amount of interference between the bullet and case mouth inside diameter and the peak push force was unexpected.

Converting the peak push force to shot start pressure using the bore area of the cartridge in question, the average and standard deviation in shot start pressure was calculated. This information is shown in Figure 7.

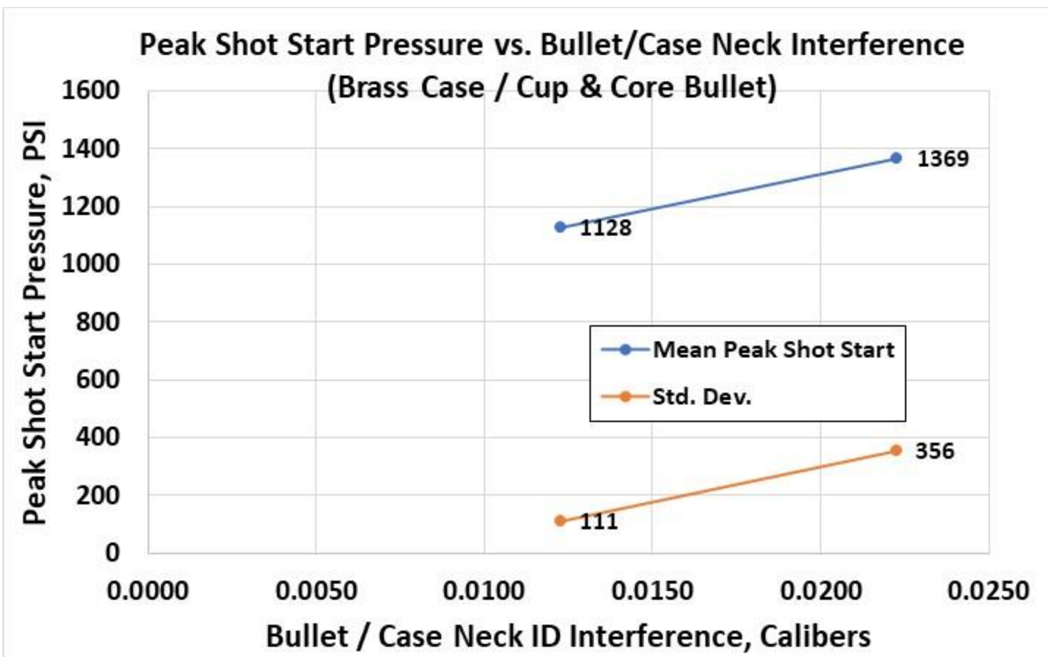

Figure 7: Mean & Sigma of Peak Shot Start Pressure vs. Calibers of Interference

Observations:

With the shot start pressure determined from measurements, a lumped-parameter interior ballistics code known as “modified Baer-Frankle” was used to assess the expected effect varying shot start pressure on peak pressure and muzzle velocity for a typical 30-06 cartridge. The results of the varying shot start pressure from varying neck tension were then compared to the interior ballistic performance of the same cartridge, bullet and propellant mass with a statistically likely increase in peak engraving pressure. Figure 8 shows the standard deviation (AKA “sigma”) of push force during the bullet transit through the barrel forcing cone as a function of bullet travel and projectile type. These measurements were made in the 2000 timeframe by pushing projectiles through barrel sections on an Instron machine at a local university. While the push force test was conducted at a much slower rate than the bullet would be traveling during the firing event, and the barrel cannot grow in internal dimension during the engraving event due to the lack of internal pressure during the push force testing, nevertheless, the testing provides a reasonable idea of the variability in bullet engraving force encountered when the bullet traverses the barrel forcing cone.

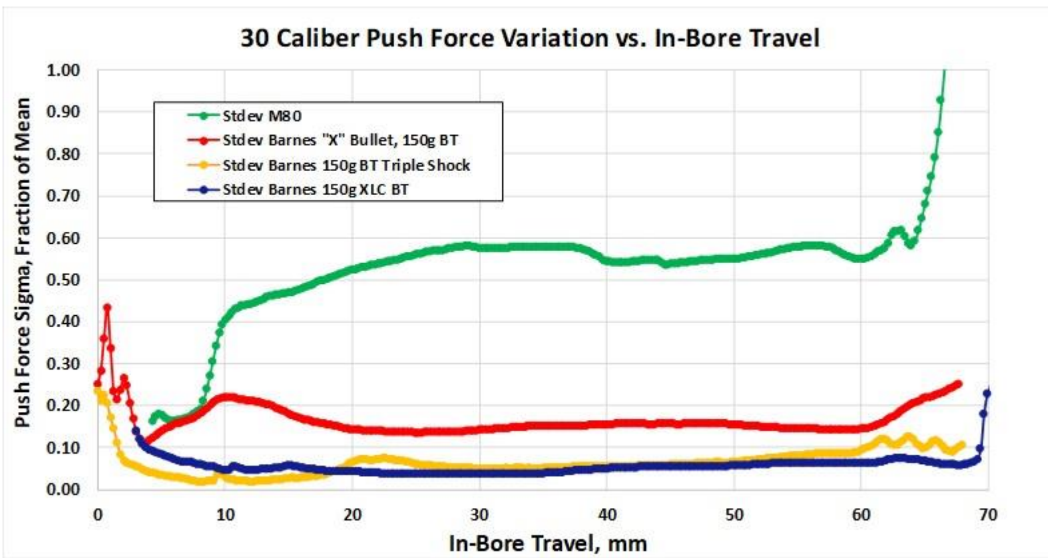

Figure 8: Measured Engraving Force Sigma vs. In-Bore Travel and Bullet Type

As is shown in Figure 8, the lowest engraving force variation that might be expected from a bullet is around 5% of the average engraving force. The shot-to-shot variability in engraving pressure is a factor completely OUT of the control of the shooter/reloader, no matter what is done to the firearm or ammunition.

Table 2 lists the engraving pressure vs. in-bore travel values used for the interior ballistics study. The first five interior ballistics simulations used the same down-bore resistance pressure, while varying the shot start pressures as was measured during the push force testing. The last interior ballistics simulation used the baseline shot start pressure, but increased the engraving pressure by 5%, according to the data shown in Figure 8. The purpose of this simulation to determine whether the effect of normal shot-to-shot variation in engraving pressure on peak pressure and muzzle velocity changes was larger or smaller than the effect of variation in shot start pressure.

Travel	Resistance Pressure	+1 Sigma Peak Engraving
inch	psi	PSI
0.00	500.0	500.0
0.05	500.0	500.0
0.09	5262.2	5525.3
0.13	9209.8	9670.2
0.22	9209.8	9670.2
0.38	9209.8	9670.2
0.42	7691.5	8076.0
0.47	6173.2	6481.8
0.57	5262.2	5525.3
0.67	4351.2	4568.8
1.19	3440.2	3612.3
1.71	2529.3	2655.7
2.96	2073.8	2177.5
4.20	1618.3	1699.2
6.28	1466.5	1539.8
12.50	1314.6	1380.4
18.73	1162.8	1220.9
24.95	1011.0	1061.5
415.05	1011.0	1061.5
622.55	1011.0	1061.5

Table 2: Baseline and Modified Engraving Pressure vs. Travel for Interior Ballistics Study

The results of the interior ballistics study are shown in Table 3. Here, the **average** (AKA "Baseline") simulation lists a peak pressure of 54524 PSI, with a muzzle velocity of 2836 FPS. Simulations were done to assess the effect of plus and minus 1 & 2 standard deviation (e.g. sigma) of shot start pressure on the interior ballistics performance, and those results are shown. Assuming a Gaussian distribution of interior ballistics behavior, simulations of minus 2 sigma to plus 2 sigma would encompass 95% performance population. As shown in Table 3, the muzzle velocity variability caused by changes is shot start pressure would be expected to account for no more than approximately a 4-7 FPS change in initial velocity. On the other hand, the simulation ("+1 Sigma Engraving") that used the baseline shot start pressure, but increased the engraving pressure by 5% (one standard deviation), would be expected to result in an approximately 10 FPS change in muzzle velocity. This change in muzzle velocity completely swamps the velocity changes seen with changes in shot start pressure using no variation in engraving pressure.

	Shot Start, PSI	Pmax, PSI	MV, FPS
-2 Sigma	278	53777.5	2829.0
-1 Sigma	389	54161.3	2832.8
"Average"	500	54524.3	2836.3
+ 1 Sigma	611	54784.2	2838.7
+ 2 Sigma	722	54979.2	2840.3
+1 Sigma Engraving	500	55552.94	2846.0

Table 3: Interior Ballistics Performance Summary Varying Shot Start & Peak Engraving Pressure

Using closed form equations to estimate the coefficient of friction between the case neck and the projectile shank, the fitted static friction coefficient was determined to be approximately 0.008 for the 25 caliber case/bullet and 0.015 for the 30 caliber case/bullet.

Conclusions:

It appears that the use of case mouth annealing to reduce shot start pressure variability can only have limited benefits when considering interior ballistics repeatability with a goal of reducing muzzle velocity variations. As shown by simulation, the shot-to-shot changes in engraving pressure completely swamp the effect of any improvement in shot start pressure consistency which case mouth annealing might provide.

Case mouth annealing will certainly help prolong case life, but any real or imagined reduction in group size is likely to be related to something other than a reduction in muzzle velocity variability.