The Los Angeles Silhouette Club

A Few Comments on Cast Bullet Alloys

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Cast bullet hardness, specifically the hardness of the various alloys used to make cast bullets, has raised a lot of questions and confusion lately. A very common misconception is that leading is caused by the bullet being too soft and the lead gets stripped off or abraded away from the bullet's bearing surface as it passes down the bore. This misguided belief leads many new bullet casters to turn to expensive alloys like linotype, and/or elaborate heat treating methods to harden their bullets, thinking that this is the only way to prevent leading.

There are very, very few revolver applications that require a BHN of over 20. In my experience, revolver leading can almost always be traced to some other factor (inadequate lubrication, improper sizing, barrel/frame constriction, etc.). Only very rarely is barrel leading caused by the bullet being too soft. In support of this claim, let me point out that many muzzle loaders prefer bullets cast from 30-to-1 alloy (which is quite soft, BHN of about 9) and these smokepole slugs are routinely driven to 1300-1400 fps. In addition, high-velocity .22 Long Rifle ammo uses an even softer bullet at over 1200 fps (and if a .22 leads, it's a gun problem, not an ammo problem). Elmer Keith's favorite cast bullet alloy was 16-to-1 lead/tin, which has a BHN of only 11. This is the alloy that gave a roaring birth to the .44 Magnum using plain-based cast bullets loaded to 1400+ fps. Properly loaded and lubed, Elmer's alloy will leave a magnum revolver barrel shiny and clean after a long day shooting.

Plainly stated, hard-cast bullets with a BHN well over 20 are simply not necessary for the vast majority of handgun applications. A novice bullet caster can have much of his or her new-found enthusiasm quenched by the clamor, confusion and paranoia surrounding bullet hardness. This is a shame because understanding alloy suitability is not that complicated and bullet casting really is a lot of fun and allows a shooter (novice and master alike) to get so much more out of their hobby.

Just about every conceivable alloy has been used at one time or another to make bullets. The cast bullet alloys most commonly encountered today are linotype (12% antimony, 4% tin, BHN of 22), Lyman #2 alloy (5% antimony, 5% tin, BHN of 15), and wheel weights (the composition varies somewhat, but usually runs 3-4% antimony and about 0.5% tin and a BHN of 10-12). These hardness values are for air-cooled bullets; heat treating or water quenching these alloys will raise these values notably. For an excellent, detailed treatment of the metallurgy of lead-tin-antimony alloys and how their properties can be best exploited by bullet casters, the reader is wholeheartedly referred to the Lyman Cast Bullet Handbook, "Cast Bullets" by the NRA and "The Art of Bullet Casting" by Wolfe Press. My intent here is to provide an easily digested overview so that new casters will have a clean and simple introduction to the subject and start casting good bullets as quickly as possible.

Historically, tin was used to harden bullet alloys because it was widely available, it was easily mixed with molten lead, and it improved the "cast-ability" of the alloy considerably (tin lowers the surface tension of the molten alloy and allows it to fill out the mould more completely). However, in recent years tin has gotten to be rather expensive. In addition, it's really not all that effective at hardening lead alloys. Antimony hardens lead alloys much more effectively than does tin, and is cheaper to boot, so antimony is the primary hardening component used in lead alloys today. In addition, antimony allows the alloy to be hardened via heat treatment, something the chemistry of tin doesn't allow (and arsenic is even better for heat treating than is antimony). Antimony has limited solubility in molten lead, but tin enhances its solubility through the formation of an inter-metallic SnSb compound, which is more soluble.

Thus each component contributes something different to the whole: tin provides cast-ability (2% is really all that's needed) and "mix-ability", antimony provides hardness and the ability to harden through heat treatment, and a small amount (0.05-0.5%) of arsenic (which in and of itself doesn't harden the alloy appreciably) significantly enhances the heat treat-ability of the mix.

There's been a lot of interest in recent years about making cast bullets very hard (BHN of 20 to 35), either through the use of very high antimony content (e.g. 12%), water quenching or heat treating. The only time that such hardness is needed by a revolver shooter is when dealing with very high pressure, high velocity loads (e.g. .454 Casull). If the hardness isn't required, why use linotype at $1 a pound for sixgun fodder when wheel-weights are free, or at most about 15 cents a pound? Remember, the mighty .44 Magnum was born with plain-based cast bullets with a BHN of 11 ... and Elmer was pleased.

The metallurgical details of what happens to lead-tin-antimony alloys during heat treatment are beyond the scope of this article, but Dennis Marshall has an excellent treatise on this subject in "Cast Bullets" by the NRA. The bottom line is that lead alloys that contain antimony can be hardened considerably (10 or more BHN) by heating them to about 400F degrees for an hour or two, and then water quenching. Small amounts of arsenic enhance this tendency considerably. Somewhat similar results can be obtained by casting fast and hot and quenching the hot bullets in water (keep the water away from the lead pot and use some sort of splash control!).

It is important to recognize that lead-tin-antimony alloys work soften (as opposed to brass and steel alloys that work harden), so sizing the bullets will soften those areas of the bullet that get worked. If I'm going to shoot heat-treated bullets, then I size them first (but apply no lube), heat treat, then lube in the same sizing die (this time-consuming process is why I shoot so very few heat-treated bullets). If I'm shooting water-quenched bullets, I choose a sizer die that is just large enough that very little sizing occurs and just run the bullets through one time to get lubed (MUCH quicker and easier).

Tin and lead are infinitely soluble in one another and their binary alloys form true solid solutions. This is how chem-geeks and metallurgists say that the tin is evenly mixed throughout and does not separate. Antimony is much less soluble in lead, and lead-antimony alloys generally have some degree of phase segregation (i.e. antimony crystals surrounded by lead alloy). Lead-tin alloys tend to be much more malleable than do lead-antimony alloys, so straight lead-tin alloys are better suited for cast bullets that are intended to expand readily (i.e. hollow points), especially at lower velocities. They mushroom more smoothly and are less prone to fragment. At higher velocities, a small amount of antimony is acceptable, but it should be limited to no more than 3% to minimize brittleness and fragmentation. The harder (and more brittle) antimony alloys are better suited for bullets that are not meant to expand.

Why not just cast all revolver bullets out of linotype (BHN = 22)? The short answer is because barrels aren't perfect. The long answer is because cast bullet obturation is a good thing. Obturation is the plastic deformation of the bullet alloy as a result of the pressure applied to the base by the burning powder. By making the bullet soft enough that it can deform slightly upon firing, it does a better job of sealing the gases off behind it and minimizing blow-by and the leading that results from it.

Usually when obturation is brought up, the topic of conversation is groove diameter. I'd like to suggest that perhaps this is inappropriate. Most barrels made today are cut with a pretty consistent groove diameter; it may be "tight" or it may be "loose" but it will usually be reasonably consistent throughout its length, generally within +/- .0005" (this didn't used to be true). However, the width of the grooves/lands may well vary by several thousandths. The reason for this is during the repetitive operation of cutting the grooves, the placement of the cutter may not be exactly reproducible, or there may be chatter, or localized hard or soft spots so the cutter drags or skips. Yes, modern barrel-makers are very, very good; but minor variations in the cutting operation, or minor defects within the barrel steel can make the grooves/lands vary ever-so-slightly in width. The forward edge of the land is of little consequence because the bullet's forward momentum is continuously forcing it into this edge. Where the variation of groove/land width raises its hoary head is on the trailing edge.

Once the bullet is engraved, if the land/groove width varies, then the seal is broken on the trailing edge. How many times have you seen barrel leading "follow the rifling"? That is a sure sign that the bullet was too hard for the pressures generated by the load. This is why bullets of moderate hardness are desirable, by obturating they can seal this trailing edge. At extremely low pressures (e.g. 600-700 fps) obturation isn't quite as important since at these low pressures blow-by isn't as much of a problem and the lube serves as a floating fluid gasket and seals the gases (thereby limiting blow-by). Unfortunately, at the higher pressures that most sixgunners operate at, the lube gets blown out the muzzle if it doesn't have obturation playing a supporting role.

So, for routine sixgunning applications what do we want from our cast bullet alloy? In the 800-1000 fps range we should probably keep the alloy at a BHN of 12 or below. From 1000-1400 fps, 12 to 16 is a very useful range of hardness. For velocities of 1400 to 1700 fps, this window slides up to 14 to 20. Above 1700, linotype at a BHN of 22 is an excellent choice.

What does this mean in terms of alloys? For general all-round revolver shooting, I find it hard to beat 10 lbs of wheel weight alloy with a couple ounces of added tin. This comes out to roughly 4% antimony, 2% tin (similar to the old electrotype alloy). This makes excellent bullet metal, it casts well and is hard enough for almost all handgun applications (BHN of about 12). If harder bullets are called for, then this alloy can be water quenched from the mould (or heat treated), which raises the hardness considerably, and I commonly do this for my .44 Mag cast bullets. Its not really necessary, but the water quenched bullets are a little bit more accurate and water quenching is so easy to do, so why not? I tend to think of this approach as "tight-wad's linotype". I haven't actually measured the hardness of this alloy, but I would guess that it's running around a BHN of 18 or so. It's hard enough, put it that way...

That pretty much covers the non-expanding cast bullets. When I'm casting hollow-point bullets intended for full-house magnum loads (1200-1400 fps), then I soften WW alloy a little bit by using 8 lbs WW with 2 lbs pure lead and a couple ounces of tin. By diluting the antimony with a little extra lead, this alloy comes out a little softer (about 3% antimony, 2% tin) and has a BHN of about 11, and similar to the alloy used by Elmer Keith for his cast HP's (less brittle, more malleable, and very shoot-able). An alternate for this alloy is to mix Lyman #2 alloy with an equal part of pure lead.

For lower velocity HP loads (below 1000 fps), I have grown fond of using 25-to-1 alloy (6 lbs pure lead with ½ lb of 50/50 solder). This alloy is soft enough (BHN of about 9) to expand readily at impact velocities down to about 850 fps (depending on the HP design) and is very useful for things like .38 Special and .44 Special loads. It casts beautifully!

I only resort to using linotype for cast bullets that will be shot above 1700 fps. Expensive high antimony or high tin alloys are really not needed for high-quality revolver loads. Medium hardness alloys will do just about everything you need for sixgun shooting. If you decide that you want them to be somewhat harder, then just water quench the bullets as they drop from the mould. Most leading is caused by some form of dimensional mismatch or by inadequate lubrication, not by the bullet being too soft (don't blame the alloy for something it didn't cause). As the old adage goes, "Moderation in all things..."

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The LASC Front Page   Index to all LASC Articles

Glen E. Fryxell Article Index