Using Tungsten Powder in Small Arms Projectiles

by

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Synopsis: Five design characteristics are identified for the use of tungsten powder in bullet design, with techniques to put the theoretical benefits into practice with conventional swaging equipment. The goals which can be achieved include: (1) non-toxic, non-lead bullets which meet OSHA objectives for indoor shooting range airborne lead exposure, and for long-term outdoor environmental protection from lead contamination; (2) use of heavier than normal weights without the need to replace standard 1-10 to 1-14 rifling twist rate barrels with faster twist rates for stability; (3) use of conventional weight bullets in a shorter package, allowing for additional powder capacity or improved feeding through the action in certain calibers; (4) shifting of the center of balance independently of the center of form, so that experimental tuning of the bullet weight and balance can be achieved for optimal accuracy by using a combination of tungsten and polyethylene for sectional core materials; and (5) delivery of higher than normal energy to the target with limited material penetration, useful for law enforcement and security forces in populated areas.

What is Tungsten?

The word tungsten is Swedish for heavy stone . It is an elemental metal with a greyish-white luster, which is a solid at room temperature. Tungsten has the highest melting point and lowest vapor pressure of all metals, and at temperatures over 1650°C has the highest tensile strength. It has been used as the filament material in electric light bulbs since the invention of this application in 1913 by Coolidge. It has excellent corrosion resistance and is attacked only slightly by most mineral acids. The chemical symbol for tungsten is W, which stands for wolfram. Medieval German smelters found that tin ores containing tungsten had a much lower yield, because the tungsten devoured the tin like a wolf . Pure tungsten metal was first isolated by the DeElhujar brothers, two Spanish chemists, in 1783.

Tungsten appears to have no harmful affects on human health, other than a possibility of irritation of the eyes or lungs from exposure to airborne powder. Because it is a stable element, it tends to pass through the body harmlessly when ingested. Studies by a Russian group indicated a possibility of lung cancer from breathing of tungsten dust, but other studies have either contradicted the results or have been inconclusive. In general, the risk of using tungsten powder seems to be of the same order as road dust or any other fine particles which can irritate the lungs if breathed in sufficient quantity.

Because tungsten is heavier than lead, with a density of 0.697 pounds per cubic inch (as opposed to 0.479 pounds per cubic inch for lead), and is stable at high temperatures, the use of tungsten instead of lead for bullet cores (the filling or center of a jacketed bullet is called the core) offers several theoretical benefits. Tungsten has no known toxicity to humans, so the dust from impacts of tungsten core bullets against a back stop in an indoor range is inherently more safe than a conventional lead core bullet. Solid tungsten is quite hard, with a Brinnell number of 2570 (compared to 5 for soft lead and only 22-25 for hard lead alloys). This and its tensile strength of from 100,000 to 500,000 psi at rom temperature would make solid tungsten cores not only expensive to machine but quite damaging to back stop materials. Powdered tungsten pressed together at pressures of 20,000 to 50,000 psi will break up on impact of the bullet, and spread the force over a wider area instead of penetrating the back stop.

The purity and particle size of the tungsten powder is critical for effective performance in small arms projectiles. With fine particle sizes (under 10 micron diameter), the airborn dust from impact becomes excessive. Handling becomes difficult, because the material tends to bridge and clog conventional dispensers that rely on gravity feed. Measuring accurate core weights becomes tedious and thus expensive for production. As the particle size is increased, the ability to meter accurate weights is improved. A particle size of about 30 microns allows the particles to compress together well, achieving nearly the density of the solid metal, while still permitting relatively easy flow and minimal bridging.

Quality of the particle grading and the consistency of the particle shapes become critical to achieving the elemental density in a compacted powder. As the particle sizes are less carefully graded, so that mixtures from fine dust to the desired size and beyond are packaged together, the density that can be achieved drops rapidly. Air spaces between irregular particle shapes lowers the effective density of the compressed core. The so-called fines or unwanted dust particles mixed with the graded powder cause lumping and unwanted compaction during shipment and handling, so that any benefit they may contritube toward filling the air gaps is negated by the difficulty they introduce in handling and weighing the material.

Cost of the material is related to the purity, the quality control in grading particle sizes, and the quality control of particle shape. Purity of tungsten powder for purpose of maximum density is balanced against accelerated cost as the ratio of impurities drops below 0.5 percent. A standard purity of

99.5% minimum, with an average of 99.95% purity, provides adequate density at the lower end of the cost curve. Price per pound can rise by a factor or 10 or more as the purity approaches 99.99%. A purity of less than 99.0% tends to introduce unknowns that affect density, and thus bullet weight for a given volume of measured core material, as well as possible contaminants of a toxic nature. The 99.95% purity material is sufficient purity to meet the goals of the bullet maker.

Particle size and shape are perhaps more critical than the purity for achieving maximum density. Hydrogen-reduced tungsten powder, carefully graded for particle size and shape, can yield nearly the same compacted density as solid metal, in a 30 micron material. The compacted density of lesser grades often yields the same effective density as a lead core. With poor grades of material, the ability to control balance and produce either a shorter bullet with a normal weight, or a heavy bullet with a normal length, is diminished to the point where no benefit can be seen. This can lead to disappointing results and a possibility that the bullet maker will conclude there is no benefit to using tungsten powder, when in reality the benefits appear when the correct grade and purity of powder is used. There can be a strong financial incentive to try lower grades of material; using lower grade powder to save money on material may be self-defeating.

Tungsten Specifications: (CAS Registry Number 7440-33-7)

Natural Isotopes	180, 182, 183, 184, 186
Atomic Number	74
Atomic Weight	183.86
Density @ 20°C	19.3 gm/cc, 0.697 lb./cu. in
Melting Point	3410°C
Boiling Point	5530°C
Linear Coefficient of Expansion per °C	4.3 x 10e-6
Thermal Conductivity @ 20°C	0.40
Specific Heat @ 20°C	0.032
Electrical Conductivity, % IACS	31
Electrical Resistivity @ 20°C	5.5
Tensile Strength @ Room Temp	100,000 - 500,000 psi
Tensile Strength @ 500°C	75,000 - 200,000 psi
Tensile Strength @ 1000 °C	50,000 - 75,000 psi
Poisson s Ratio	0.284
Hardness (Mineral)	7.5
Hardness (Vickers)	3430
Hardness (Brinell)	2570
Working Temperature	1700°C
Recrystallization Temperature	1300 - 1500°C

Use of Tungsten in Bullet Design

Tungsten as a solid material is difficult and expensive to machine because of its extreme hardness, but as a powder, it can be compacted into a bullet jacket at normal swaging pressures used for lead core bullets. With the proper grade and quality of particle size control, tungsten powder is relatively easy to handle and compacts to nearly the same density as solid metal.

Tungsten is approximately 1.7 times heavier than lead. A tungsten core bullet having the same length, caliber and shape as another bullet with a lead core would weigh more. The exact amount could be calculated by first weighing the bullet jacket, then subtracting this from the total bullet weight, and multiplying the resultant lead core weight by 1.7, and finally adding back the jacket weight. For instance, a 168 grain .30 caliber match bullet with a lead core typically would have a 50 grain jacket and a 118 grain lead core. An identical appearing tungsten core bullet would weigh 250.6 grains.

Heavy weights in standard length bullets

The most obvious use of tungsten powder in bullet design is to make heavy bullets that will fit into normal length chambers, feed through standard length actions and fit into normal magazines and revolver cylinders. Because the bullet density is increased, and its length remains the same, the spin rate required to stabilize it does not change appreciably. This means a second benefit is that the normal twist rate of barrel should stabilize the heavy tungsten core bullet, whereas it would not stabilize a lead core bullet of the same weight (since the spin rate required increases with bullet length, and only incidently with the bullet weight because normally the density of material is not changed).

In addition to the savings in not having to purchase special barrels to fire these heavy bullets accurately, the normal length tungsten core bullets have the additional benefit of not wasting additional energy in spinning faster, and because they do not have to spin faster, they also have less problem with radial imbalances than a conventional heavy weight lead core bullet. It is well known that the faster a bullet is spun about its axis, the more centrifugal force is generated by slight imbalances in the jacket wall thickness, tiny voids or other anomolies of construction. If all else were equal, the bullet which can be stablilized with the lowest twist rate will tend to be more accurate, and this would be the tungsten core bullet. Typical uses might be 80-100 grain .224 bullets, 130-145 grain .243 bullets, and 200-250 grain .308 bullets for long range, high delivered energy hunting loads or stable target rounds, or extra-heavy handgun bullets that will not protrude either into the case or project beyond the standard cartridge length.

Short lengths with normal weight bullets

Using a dense material also means that the length of a normal weight bullet can be shortened, for such purposes as gaining additional powder capacity in the case, fitting into a short throated barrel without impacting against the rifling, or allowing the innovative use of longer wildcat cases (such as a rimmed .30 rifle case cut back to make an extra long .44 handgun case, which could fit a .44 Magnum revolver cylinder). In some situations where the limit of bullet length is all that prevents an innovative idea from working, using a normal weight with a tungsten core can reduce bullet length, and thus reduce the overall cartridge length enough to try a new concept.

The amount of reduction in length is approximately 60 percent of the original lead core bullet length, when filled with tungsten powder. This will vary with the ratio of jacket to core weight, of course, but it is normally safe to assume that a minimum of 25% shorter length will result in the same weight of bullet, when changing from a lead core to a tungsten core. A simple example is the use of a slower burning, bulkier powder behind a normal weight .380 or .25 ACP bullet when used in a pistol that has been equipped with a longer than usual barrel. The shorter bullet allows more powder room in the cartridge, which can then be used to develop safe loads that deliver a longer burn curve to accelerate the bullet through a longer barrel than would normally be used in that caliber.

(CAUTION: Nothing in this report should be construed as an endorsement of loading experiments by persons who are not thoroughly qualified to safely do so. The non-professional should not attempt to develop loads which require additional powder capacity, modified cases, or special bullet weights, but only to note that it is possible under professionally controlled circumstances, using remote firing and pressure testing equipment and careful examination of the stresses applied to the cases and firearms involved.)

Adjusting the balance of bullets

The center of form of a bullet is generally defined as the point at which all of the axial forces could mathematically be concentrated from their actual vectors. The center of gravity of the bullet is the point where the bullet could be balanced against gravity. Although the actual center of gravity and center of form are located inside the bullet, we can simulate the location of the center of gravity by attempting to balance the bullet on a razor blade. The point along the side of the bullet where it most nearly will balance is close, in practical terms, to the actual center of gravity.

The center of form is harder to ascertain by external testing, because it is a measure of the forces working upon the bullet as it flies through the air. However, we can shift the center of gravity within the airframe of a given bullet by using a combination of two different densities of material in the core, each in its own separate compartment , so that the ratio of length of each will determine where the center of gravity lies.

For instance, linear polyethylene balls are available in various diameters that will slip easily into nearly any caliber of bullet jacket. These polymer balls will compress under swaging pressure to fill the space available, yet add only a few grains to the total bullet weight. Filling the entire bullet with two or more plastic balls creates a standard length of bullet that has only a few more grains than the jacket itself. A typical example would be a 58 grain .308 rifle bullet, which is normal length for a 168 grain bullet. Another would be a 40 grain 9mm which has the appearance of a normal 140 grain bullet. These light bullets can be fired at extremely fast speeds with the correct charge of fast burning powder, but they generally are not accurate.

By placing a plastic ball into the jacket, compressing it, and then placing a small quantity of tungsten powder in the jacket followed by a final plastic ball, the weight can be increased and the balance shifted, so that a combination of material quantities and positions can be developed that will deliver good stability with any of the weights. Moving the weight toward the tip tends to make the bullet more stable, but a point will be reached where the bullet does not turn to follow the trajectory arc. At that point, the bullet is over-stable in the sense that rifling no long is required to keep it pointed nose first, but instead the mass forward of the center of form will do this. If the trajectory is very flat, or the range is quite short, the bullet will appear to be accurate.

But if the trajectory or range is normal for a rifle or long-range handgun, the bullet will be pointed in the same direction as it was when it emerged from the barrel all the way to the target. That is, it refuses to turn because it is so stable. In this case, the bullet presents an angle to the direction of flight and thus offers a very low ballistic coefficient, compared to the same bullet with the center of gravity shifted slightly further toward the rear. Extreme examples have resulted in the bullet dropping sideways through the target (and the normal wind and air currents cause it to drift in an extreme pattern from shot to shot, which appears to make the bullet seem inaccurate and in practical terms, it is).

A good use of this ability to tune the balance point of bullets is in the manufacture of ultra-light, high speed bullets that are more accurate than typically would be the case with shorter, lead-filled bullets of the same weight. An example of a .30-30 rifle firing nearly 3,500 fps with modest pressure and a 75 grain polymer/tungsten bullet (jacketed), and one of a .25 ACP achieving 2,000 fps with reasonable accuracy and only slightly elevated pressures by using a special 30 grain bullet, illustrate the possibilities. Such development requires machine rest testing with remote firing control under strict safety controls, while finding the correct loads of fast burning powder, and are not for the casual handloader. Somewhat less extreme examples can be developed by using established loading information.

Generally, it is safe to fire a lighter bullet than a loading manual specifies for a given load, but not a heavier one. The problem with extremely light bullets and standard loads is that the powder may not burn, or may cause a hang-fire (partial ignition, or slow ignition). We have had loads in which the primer simply pushed the bullet and all the unburned powder out the barrel, and others in which the bullet would not exit the barrel, but remained an inch from the muzzle after firing. Once the proper load was developed, these problems disappeared, but one must be extremely cautious about checking the barrel after each shot while developing them. Special actions are used, mounted on machine rests and fired with a solenoid or long camera shutter release device.

The general principle of balancing a bullet with two or more stacked layers of core materials of different density is that shifting the weight forward of center means a slower twist will stabilize the bullet, and sifting it toward the back means that the bullet will require more spin but will be more likely to face the direction of travel and not try to keep the same attitude or angle of firing all the way to the target. In examples where the weight was shifted far forward on the bullet, nearly equal accuracy was obtained from smooth bore barrels as from rifled ones, at shorter ranges where the trajectory was insignificant, which is of course why the Minie-type bullet with the large hollow base and weight forward design is accurate so long as the trajectory isn t excessive, even in smooth bore muskets. But generally, shifting the balance is done in small steps to achieve more modest goals: a slight tuning of the bullet may accomplish a great deal in regard to tighter groups, whereas carrying the concept to extremes may be accurate only in comparison to the same bullet weight without optimal balancing, but may result in poor accuracy in comparison with normal weight bullets.

High energy delivery without excessive penetration

Tungsten powder core bullets carry more energy than the same length of bullet filled with lead and moving at the same speed, simply because they are heavier. In some cases, penetration of high energy bullets into the target is not desired. For example, back stops at target ranges, or metallic silhouette targets, may be damaged by high energy solid core projectiles. A powdered core that breaks up immediately upon impact, and spreads its energy quickly over the surface rather than concentrating it in one point, can preserve the life of range components.

In defense situations, a higher delivered energy generally results in the ability to penetrate obstacles and clothing, but then can cause problems with penetration of walls, ceilings and floors in urban law enforcement situations, putting innocent people at risk. The powdered tungsten core will have a greater tendancy to break up after impact, but still deliver its energy efficiently to the intended target. Since the material is non-toxic, the contamination after-effects of firing many bullets into an area are virtually non-existent. This is of course more important at ranges than in actual shooting situations, but using non-toxic bullets is at least a potential good point in public relations. Since tungsten cores are more dense than lead, less volume of material is required for the same energy delivery, and there is less secondary missile material, broken into far smaller particles, reducing the chance for unnecessary collateral damages.