Propellant Geometry Type Descriptions

Smokeless propellant has three basic chemistry types; single base, double base, and triple base. Single base propellant uses only nitrocellulose as the primary energetic. Double base propellant uses nitrocellulose and nitroglycerine, while triple base uses the double base formulation, and adds an additional energetic, typically nitroguanidine.

A propellant characteristic known as "progressivity" is important because it causes increasing gas generation as the propellant burns. Progressivity can be achieved either by chemical means (via a deterrent coating on the exterior grain) or by geometry (shapes selected because their surface area increases as the grain burns). Figure 1 *s*hows the relative surface area as a fraction of propellant depth burned for typical propellant geometries.

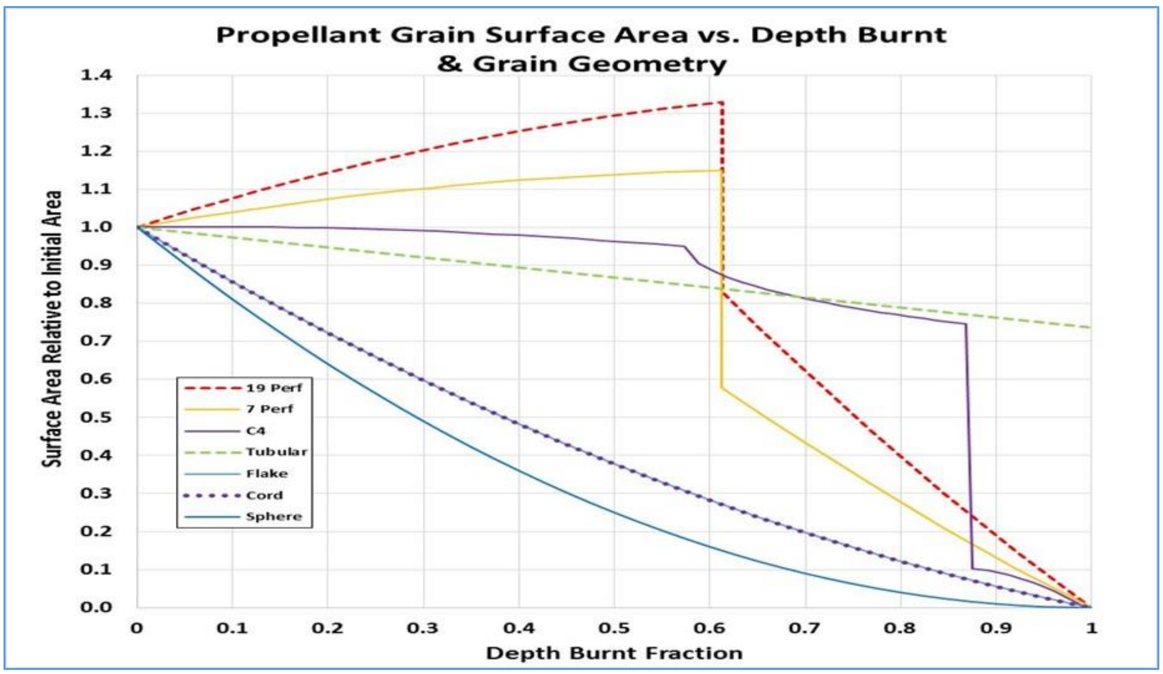

Figure 1: Normalized Propellant Surface Area vs. Depth Burnt & Propellant Geometry

Since the sphere, cord, and flake geometries have decidedly digressive area vs. depth burnt characteristics, those propellants have to use surface deterrent coatings to enable any "progressivity" to be exhibited. The tubular (single perforation) grain is ever-so-slightly digressive in geometry; the inside surface increases in area as the outside surface decreases in area, the end faces can only lose area during propellant burn.

Application of deterrent coatings (sometimes called combustion moderators) mean that when simulating the interior ballistic behavior of such propellants, the initial burn rate coefficient will be smaller than the final burn rate coefficient. When no deterrent coatings are applied, the initial and final burn rate coefficients are equal to one another.

Ammunition engineers should be aware that, best efforts of the propellant manufacturer to the contrary, there will be minor variations in propellants lot-to-lot. Thus, powder makers are usually relegated to some sort of lot "blending" of fast and slow burn stocks to achieve the desired pressure-velocity performance for a particular application. When simulating the interior ballistic behavior of propellants, it is typically assumed that all propellant possesses **exactly** the same geometry, and in lumped parameter interior ballistics codes, all the propellant grains start burning simultaneously. Neither of these conditions is technically true, but unless the user otherwise specifies, it's the assumption that is made.

Most of the propellant geometries in common use are briefly described below.

Flake:

Flake propellant is commonly used in applications where rapid and complete combustion is of primary importance. In these applications, the peak pressure is usually much lower than other high performance ammunition, and projectile mass/diameter ratio is usually low, meaning the volume in which the propellant expands will grow very quickly by projectile movement. This would otherwise cause rapid pressure fall-off unless the powder is consumed rapidly. This propellant geometry typically uses no exterior combustion inhibitors (e.g. deterrents) to further enhance the ability of the powder to burn rapidly. Chemically, flake powders are usually double base formulations. Typical applications for this powder geometry include: Pistol and shotgun cartridges, blanks and Mortar Charge increments.

Flake propellants are made by shaving extruded propellant cords into thin flakes. The thickness of the shaving controls the powder "web", the minimum dimension which must be burned for the propellant to be completely consumed. Figure 2 shows a close-up of flake propellant geometry. Note the sharp corners on the perimeter of the grains.

Figure 2: Flake Propellant (700-X)

Ball:

“Ball” powder is a Trademark of the St. Marks Powder Company for its brand of spherical double base (e.g. nitrocellulose and nitroglycerine) propellant. While the propellant grains start roughly spherical, they are commonly “rolled” to change (flatten) their shape to an oblate spheroid to enhance loading density and ignitability. Depending on the exterior deterrent applied to the propellant, it is commonly tailored for applications from pistol cartridges up to 25x137mm direct fire ammunition and mortar propelling charges. Figure 3 shows two Ball powder variants; W748 is on the left and W231 is on the right.

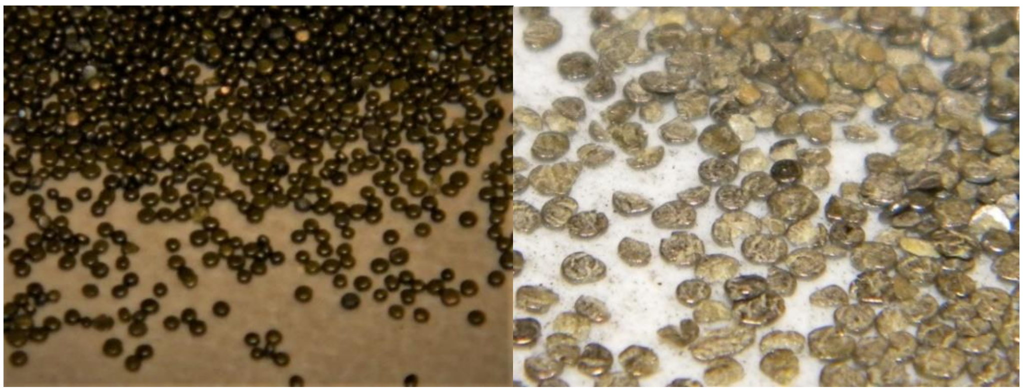

Figure 3: Ball Powder (W748 & W231)

The W748 has a significant amount of deterrent coating (~5%) applied to its exterior and is only slightly “rolled”; it is intended for use at high pressures in rifles. The W231 is a ball propellant with no deterrent coating on its exterior and significantly rolled to control the propellant web. This powder is typically used in pistol cartridges. Note the more rounded corners of the W231 propellant grain in Figure 3 compared to the fairly sharp edges of the Flake powder shown in Figure 2.

Cord:

Cord propellant is in the shape of a right circular cylinder; it is formed by pressing plasticized propellant through an extrusion die. The cords are cut to a length close to the grain diameter to facilitate desirably dense loading. Cord propellant can be made with either single base or double base chemistries. Applications range from rifle to 25x137mm.

Figure **4** show an example of a cord propellant grain.

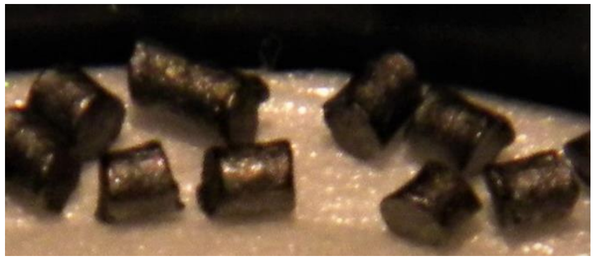

Figure 4: Cord Powder

Single Perf (Tubular):

Single perf(oration) propellant is in the shape of a right circular cylinder. It differs from cord propellant in that it has a hole along the grain axis to allow the interior to burn from the inside out, as the exterior burns from the outside in. Single perf, tubular powders are made with a variety of deterrent levels depending on the application. For example, Blackhorn 209 is a black powder substitute intended for use in muzzle loading firearms and as a result, this powder uses no deterrent to help with ignitibility. The IMR powder series manufactured by GD-OTS in Valleyfield, Québec has significant deterrent coating applied to its exterior to allow for use at high pressures in rifle applications. Single perforation propellant grain geometry is used all the way up to 155mm propulsion charges; with combination of web size and deterrent coatings specifically tailored for the required task.

Figure 5 shows single perf IMR 3031, intended for use as a high-pressure rifle propellant, is on the left and single perf Blackhorn 209, a black powder substitute, is on the right.

Figure 5: Single Perforation Tubular Propellant (IMR 3031 & Blackhorn 209)

The geometry of Blackhorn 209 is chosen specifically to limit the loading density of the extruded grains, and enhance the permeability of the propellant bed to the ignition flame front. Like the cord propellant, it is formed by pressing plasticized propellant through an extrusion die, but this die has a pin suspended in the center of its axis by a thin metal sheet called a "spider". The red circle on the right-hand side of Figure 5 indicates a propellant grain that shows signs of the "spider" used to support the pin in the center of the forming die used to shape the propellant grain.

7-Perf:

The 7-perf propellant is in the shape of a right circular cylinder, and it expands on the single perf grain by adding 6 more perforations in a hexagonal arrangement surrounding the center perforation. These grains are made typically in double base or triple base chemical formulations and with few exceptions, these grains typically do not have deterrent coatings applied to their exterior. Usage extends from 25x137mm to 155mm artillery applications; these powders typically launch projectiles that are on the low end of the bullet mass/diameter spectrum for the smaller calibers in which it's used. Figure 6 shows the perforation arrangement of a 7-perf propellant grain.

Figure 6: 7-Perf Propellant Grain

19-Perf:

The 19-perf propellant grain is also in the shape of a right circular cylinder, and it expands on the 7-perf grain by adding 12 more perforations in an evenly spaced arrangement surrounding the center 7 perforations. Figure 7 shows a 19-perf grain intended for use in an artillery application (203mm) in original state (left) where the perfs are barely visible, and a partially burned state (right) where the perfs are clearly visible. This propellant geometry can be made with any previously mentioned chemical composition.

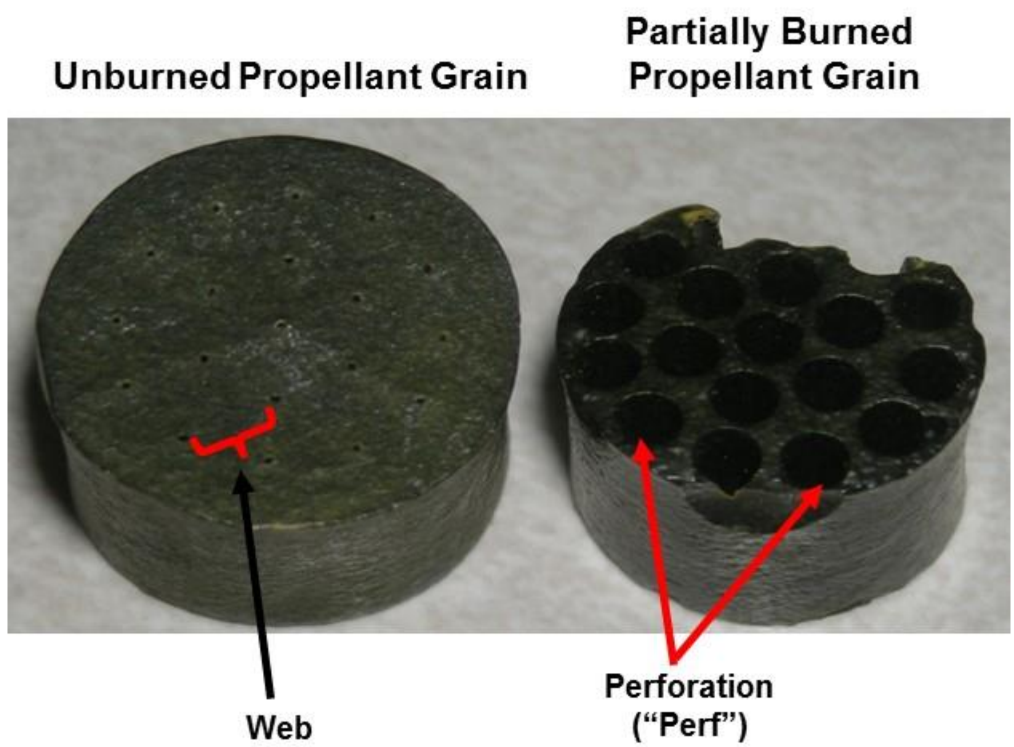

Figure 7: 19-Perf Propellant Grain

Due to the large physical size of these propellant grains and the limited chemical permeability of the grain to typical deterrents, grains with perforation counts above 7 are typically manufactured without exterior combustion moderators. This means the initial and final burn rate coefficients are equal. This propellant grain geometry is typically used in tank and artillery calibers; in tank applications it’s most common to find it used for low bullet mass/bore diameter projectiles like APDS or APFSDS bullets.