INTERRELATIONSHIP OF PARTICLE SIZE, BURN RATE AND VISCOITY

The relationship between oxidizer particle size and the burn rate and mixing viscosity of propellant confuses many people. However, when you know what is actually taking place, it all makes sense.

Let’s start with the binder, or in our fuel, R45 (HTPB). The binder and the chemical agents that “cure” it, hold the dry components in place by locking them into a plastic matrix. To do this, the binder must coat all of the particles that are present in the mix. When the binder is cured, the particles are locked into the binder and the result is “solid” propellant.

The smaller the particles in size, the more of them it takes to make a gram (or an ounce or whatever). The smaller particles also have more surface area than an equal weight of larger particles. When the oxidizer is added to a mix, it must be coated with binder. It takes more binder to coat an equal weight of 200 micron (smaller particles) AP when compared to 400 micron (larger particles) AP. More of the binder is left to act like a liquid in mixes with larger particles. The net result of this is that mixes that contain larger particles tend to have a lower viscosity than mixes which contain more of the smaller particles. AP was used in our example because most of the propellant is ammonium perchlorate. The same hold true of any solids in the propellant (i.e.: metals, other oxidizers, etc.)

Since smaller particles have more surface area, they can react more vigorously during the burn. This is true because the burn takes place on the surface of the particles and the more surface, the more burn. (In the case of oxidizers the oxygen is liberated from the surface of the oxidizer particle). This larger surface area equals faster burn rate relationship and is true of both propellant surface area and of particle surface area, and for the same reason. The only real difference between the two (propellant surface and particle surface) is in the scale.

Since a more vigorous burn will create more hot gasses and consequently more pressure, and because ammonium perchlorate propellants are pressure sensitive (burn faster as the pressure increases), the finer the particle size of the solids, the faster the burn time of the propellant. In other words, surface area(s) and pressure determine the burn rate to a great extent.

Since “commercial” propellant needs to be pourable, so that it can be mass-produced, some of the solids are replaced with binder (liquid) and this results in a less powerful propellant. Manufacturers try to offset some of this loss by replacing some or all of the AP with finer AP as in replacing 400 micron with 200 micron. By doing this the weight of the AP stays the same but the surface area is increased and so is the burn rate.

Bottom line (literally):
Smaller Particle Size = More Surface Area = Thicker Propellant Mix = Faster Burn Rate.