Making Sugar Propellant Grains

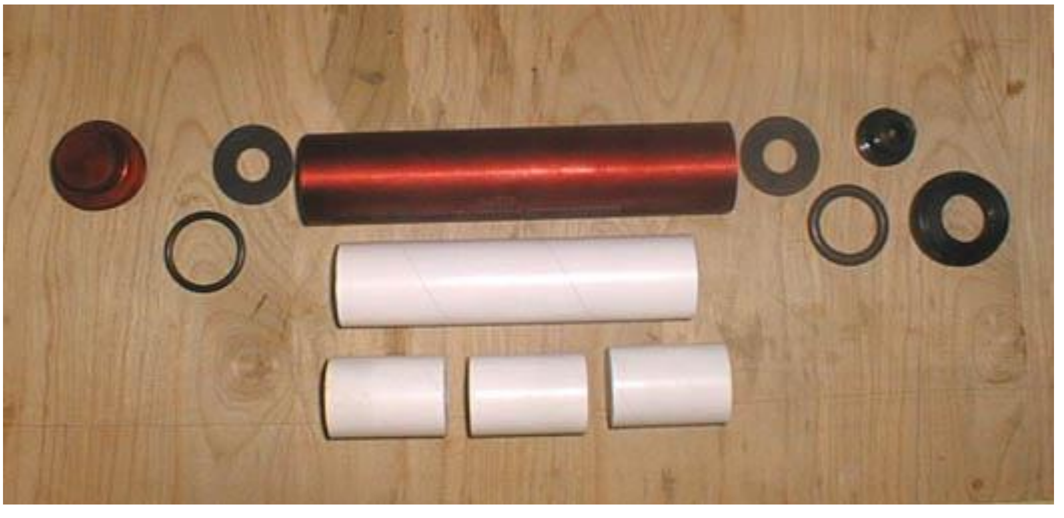
January 11, 2003

Project Parameters:

- Develop sugar propellant based high power motors that utilized commercial hardware that I already owned.
- Easy to assemble from relatively easy to purchase supplies
- Cheap to make!

Much of the development work with sugar propellants propellants in the past has utilized custom motor hardware to contain the propellant. A range of materials including aluminum, steel, phenolic and even PVC have been used successfully. The we will utilize readily available commercial hardware for the testing and demonstrations. This approach also serves as an "easy entry" for new developers since it eliminates the need for expensive machine tools and facilities.

Parts List- Motor



The place to start is the motor hardware. One Aerotech (or Dr. Rocket) 38mm reusable rocket motor with a 360 casing is required and can be purchased through most hobby shops and online rocketry vendors. These are the "reusable" parts of the motor we are making. The purchased hardware should include:
* Casing- 360 size
* Plugged Forward Closure
* Aft Closure

Note that the "Plugged Forward Closure" is not typically sold as part of a complete motor and is usually purchased separately. The rest of the parts are used one time only. Many can be made at home, or purchased more cheaply in other places, but for the sake of simplicity they can all be purchased online from RCS in small quantities in their entirety. RCS part numbers are included.

(1) 1 Casting Tube- 1.308" O.D. X 1.274" I.D. X 22.75" Long (part no. 03170)
You will need to cut three 1.8" lengths of this for casting grains

(1) Paper Motor Liner- 1.380" O.D. X 1.313" I.D. X 5.625" Long (part no. 02060)

(2) Forward and Aft Insulator Washers- 1.375" Dia. X .062" (part no. 05404)

(1) Forward O-ring- 1-3/8" O.D. X 1-1/8" I.D. X .139" Thick (part no. 00216)

(1) Aft O-ring- 1-3/8" O.D. X 1" I.D. X .210" Thick (part no. 00318)

(1) Nozzle- 1.000" O.D. X .180" Throat X .438" Exit (part no. 01500)

This will be drilled to the proper nozzle diameter during construction

While it is entirely feasible to add proper delay o-rings, liners and commercial delay grain (or homemade) with a standard forward closure, I have left these out at this time to keep a simple focus on propellant.

Parts List- Propellant
The two critical ingredients for the propellant are the oxidizer and fuel. Both of these can be purchased online from companies such as Firefox etc. at a range of prices. For successful propellant, it is important that the components be in a fine powder form. Many experimenters have had great luck with grinding granular forms of these materials to powder with coffee-grinders etc. Beginners may wish to purchase materials in the fine powder form initially. This insures good useable results immediately. The part numbers for Firefox are listed below:

* Potassium Nitrate - Stock #C170 - OX

* Sorbitol - Stock #C187C6

While there are many different grain designs that can be utilized in motor design, the Bates grain is probably the most common and simple. The demonstration motors will utilize this grain configuration and were designed using software (SRM.XLS) provided by Richard Nakka . The grain dimensions used in Aerotech commercial reloads provide satisfactory proportions for these motors as well, so will be used for the demonstration. They have the added advantage of allowing the full range of Aerotech casing sizes to be utilized. With a little work, a more uniform burn could be achieved by varying the length and core size of these dimensions but we will leave that for further experimentation. For the demonstration, we will be utilizing the Sorbitol propellant and will outline it's preparation here.

The first step is to measure out 6 oz. (170 g) of Potassium Nitrate and place it in a suitably sized "Rubbermaid" type storage bowl. Accuracy is everything here. A triple beam balance is pretty much essential, but if you are handy you can rig up a pretty accurate balance (see Richard Nakka's web site for an example). Now add to this 3.23 oz. (91.5 g) of Sorbitol and place the lid on the bowl. Shake the bowl vigorously for 5 minutes (use a timer). It is essential that the propellant is mixed thoroughly. See Richard's site for a home made propellant mixer that he recommends for consistent results. I have had consistent results with the hand mixed method, but batch sizes are limited to what your arms can endure for 5 minutes. My limit seems to be about 5 propellant grains worth at one time!

To "cook" the grains, a temperature-controlled deep fryer seems to be the tool of choice. While many have successfully created propellant by mixing directly in the fryer, beginners should probably start with the technique outlined below, which utilizes an oil (Crisco vegetable shortening) bath and a secondary container for propellant. The photo below shows my setup, including the metal strainer that came with it. This helps keep the mixing bowl off the bottom of the pan. While most deep fryers have a dial with temperatures printed on it, they are usually not very accurate. It is best to utilize either a traditional "candy" thermometer or a digital thermometer with probe to insure the proper temperature is reached. Set the fryer to about 250 degrees F and melt the Crisco in it to a depth of about2 inches. Place the thermometer in now and adjust the dial of the fryer until the oil maintains about 250-260 degrees F.

Place a stainless steel bowl in the oil bath (a handle on the bowl is pretty handy) and let it come up to temperature. Place half of the mixed propellant in the bowl. Use a wooden spoon or mixing stick to gently stir the powdered propellant every 20 seconds or so. The powder will slowly begin to melt. Once the initial batch is melted, add the remaining powder to the bowl. Continue mixing until this has melted as well.

A smooth white/ivory colored paste should now be well mixed (no lumps) and ready to pour into your casting tubes.

Place a piece of waxed paper on a wooden cutting board. Stand three precut casting tubes on end on the waxed paper. Allow a few inches between them so that you have room to place the propellant in each. A Popsicle stick works best for placing the hot propellant in the casting tubes. Scoop out a "dollop" and immediately place it at the bottom of the tube. Continue to place more propellant in the tube, being careful not to trap air as you go. If the propellant is continually placed in the middle, it tends to melt out towards the edges and eliminate air pockets. Fill the casting tube flush to the top, and use the Popsicle stick to flatten the top even with the tube. The propellant stays pretty hot in the tube so working time is not a problem with this propellant. Make sure that the tube does not lift off the wax paper while filling. If it does, then push it back onto the surface. Any propellant that leaked out can be trimmed off later. Fill each of the three tubes with the same technique.

Once filled, let them cool overnight.

The cores can then be drilled with a drill press. The demonstration motor utilizes a 3/8 inch core, but a 1/2 inch core might be better for beginners since it is less prone to erosive burning. When drilling the cores, it is a good idea to clean the bit between grains. The bit will tend to fill with propellant and will not pass the shavings of later grains out. This will lead to rougher cores that might create an initial thrust spike due to the added burning surface area. A "spade" bit tends to work best of all and does not clog like the twist drill bit.

Conclusion:

The grains are now ready to be assembled into a motor.

Assembling Motors

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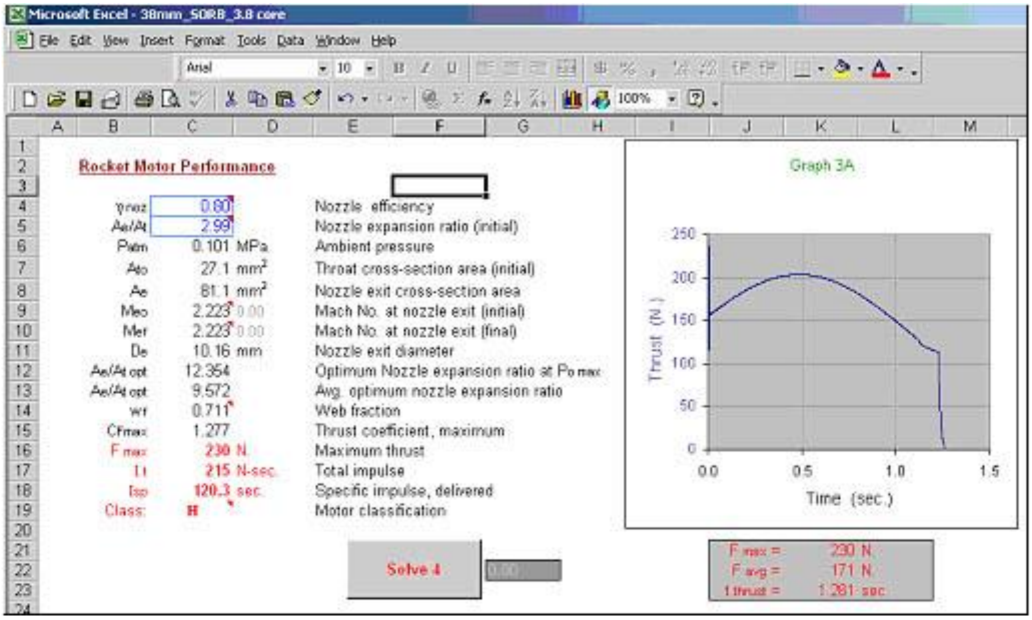
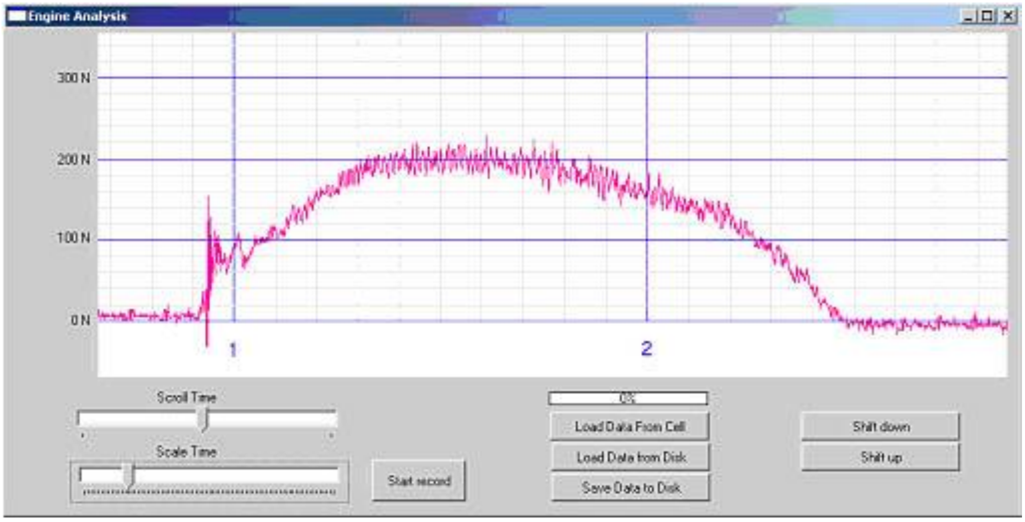
The grains that were created on the Melt/Cast Grain Preparation page match the dimensions of Aerotech commercial 38mm AP Grains. This allows the same motor assembly method to be followed that is familiar to many already. The motor that we will be assembling is calculated to be an H180. It will have a total impulse of 215.5 N-sec. Before beginning assembly, the nozzle must be drilled to the proper diameter. The diameter should be 15/64 inches for the 3 grain sorbitol motor demonstrated here. The motor liner should first be lightly coated with petroleum jelly (or even better, use Radio Shack Lubricant with Teflon part no. 64-2326). The threads of the closure are also lubricated and the O-rings are lightly lubricated per Aerotech instructions. Grains are then inserted into the liner tube, and the liner tube inserted into the casing. A delay insulator is then inserted into the forward end of the casing, followed by the Forward O-ring. The Plugged Forward Closure is then screwed onto the casing. The Aft delay insulator is inserted into the aft end of the casing, followed by the Aft O-ring. The nozzle is then inserted inside the Aft O-ring, and the Aft closure screwed into place. The motor is now ready for launch.

Static Testing



The demonstration motors were designed with Richard Nakka's SRM.XLS Excel spreadsheet. A screen shot of the anticipated thrust curve is shown in the image above.



The 3 grain motor was then assembled and launched on a digital test stand to verify the performance. This graph is a screen shot of the software written to interface with a home-made digital test stand. The actual result seems to follow the predicted performance very well, differing only as expected in the initial pressure and fall off pressure ends of the graph. The spreadsheet is a very handy piece of software for designing these motors.

After the test, the motor components looked very similar to those of a typical Aerotech reload. The liner was charred on the inside, but the outside remained in good shape. The o-rings showed no visible signs of wear and might be usable again. The insulator washers were burned on the inside edge extensively, but held up well where in contact with the o-ring. The nozzle was eroded approximately 1/32 of an inch. No damage to the reusable hardware was observed.

Conclusion:

The motors performed as designed and are ready for flight!