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Cover Photo: SC Precision's Airfoiled Rail Button and Aeropack's Tailcone Retainer. Get them at: www.ApogeeRockets.com/Building_Supplies/Launch_Lugs_Rail_Buttons/Rail_Buttons/Large_Airfoiled_Rail_Buttons and www.ApogeeRockets.com/Building_Supplies/Motor_Retainers_Hooks/Screw-on_Tailcone_Retainers

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Nut Plates For Rail Button Attachment

By Daniel Cavender



Figure 1: Welded nut plates with holes for epoxy.

While we do not currently carry larger size nut plates, here is an article on how to attach them to your rocket.}

When Apogee Components doesn't have it, I use McMaster-Carr for all of my piecemeal part needs at work. What I found was a weld nut plate with multiple drilled holes that allow glue or plastic to flow through. They are a bit expensive, but after I tried these, I was sold.

I have used them for rail buttons, installing avionics bays in airframe, etc. You should be able to assess your needs and whether this technique is good for your application.



Figure 2: A rail button installed into a fiberglass tube using a welded nut plate.

{Editor's note: The 'standard size' rail buttons (www.ApogeeRockets.com/Building_Supplies/Launch_Lugs_Rail_Buttons/Rail_Buttons/1_Rail_Button_Standard) from Apogee come with nut plates, but neither the airfoiled (www.ApogeeRockets.com/Building_Supplies/Launch_Lugs_Rail_Buttons/Rail_Buttons/Large_Airfoiled_Rail_Buttons) nor the 'large-size' rail buttons do.}

The weld nut plate with its large bonding area distributes applied loads over a larger area than a plain hex nut or a rivet. The drilled holes let epoxy push up around the plate adding mechanical engagement as well as pure shear strength. The nut is welded to the plate so I don't worry much about over torquing the screw and breaking it free.

But the airframe is contoured and the plate is flat, right? The good news is that it is easy to bend it by hand in a bench vice to the shape of the airframe.

Bending the Weld Nut Plate

This was easy to do despite requiring some exertion to bend the stainless steel plate. I had a section of airframe on hand to gauge how much I needed to bend the plate. The plate will bend where it is pinched in the vice, so I start from the middle and work my way outward. I lightly pinch the weld nut plate in the vice, leaving enough of a gap between the hex nut and the top of the vice to allow me to bend the plate. Small moves are best. It's easy to put the bend in but harder to take it out. The metal undergoes what is called "work hardening", so the more you work it, the harder it becomes to get the bend out.



Figure 3: Bend lightly. It is easy to over bend the metal.



Figure 4: Bend so the curve matches the inside of the tube.

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Newsletter Staff

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Layout / Cover Artist: Tim Van Milligan
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Nut Plates for Rail Button Attachment

Bend the plate a little then re-pinch it just a bit further down and bend it a bit more. Once you finish bending one side of the plate, turn it around and start again. Take care to make the bends symmetric. I use one of the three stamped ridges in the plate as a guide. I pick one and keep it horizontal for all the bends. Test fit the weld nut plate by laying it in the section of airframe you want to use. The nut plate will not be a perfect match, but you should be able to get about 3/4ths of the plate to touch the airframe. Repeat these steps for all the nut plates that you intend to use.

Bonding the Weld Nut Plates

The hole is drilled and I have test fit my screw with a rail button on it, and everything looks like it fits well. If you can reach the nut plate with a pencil or marker while you have it test fitted, draw a circle around it so you know where to apply the epoxy. The G5000 Rocketpoxy sold by Apogee Components (www.ApogeeRockets.com/Building_Supplies/Adhesives/G5000_RocketPoxy_Pint_Package) works well in this application, because it is thick and doesn't run while the parts are being bonded.

You will not need much epoxy to bond one weld nut plate inside the airframe. It is important that you be able to apply a liberal amount in the bonding area without getting any right at the hole you drilled. Epoxy applied directly around the hole may be pushed up into the hex nut so take care in this area.

Placing the nut plate directly into position is a bit tricky. If you lay it down and then slide it into place, you will drag the epoxy around too and likely push some up into the hex nut. I first stuck the screw up through the hole and threaded the weld nut plate on the screw before letting it come into contact with the epoxy. I then lowered the nut plate into place moving directly down and turning the screw to align the contour of the nut plate with the contour of the airframe.

I then tightened the screw once the nut plate was down to apply compression. I applied a bit more epoxy where needed all around the top of the nut plate and then set it aside to cure. Done!

About the Author

Daniel is a leading researcher in nuclear thermal propulsion at NASA's Marshall Space Flight Center, and subject matter expert in the realm of amateur rocketry. He is president of the Huntsville Area Rocketry



Figure 5: Nut plate installed with epoxy to hold it in place.



Association (HARA) and has contracted with the Alabama Space Grant Consortium (ASGC) to conduct advanced rocketry workshops for NASA student launch initiative program. Daniel holds a level three certification with both NAR and TRA, and is a member of the TRA Technical Advisor Panel. Daniel encourages students to pursue science-oriented careers through hands-on experience, and promotes sport rocketry for all ages.



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Terminology Of Model Rocketry - Part 3

By Ken Kosanke

{Editor's note: Ken Kosanke has released a new product called the *Encyclopedic Dictionary of Pyrotechnics*. To promote this new reference dictionary, Ken has allowed us to reprint a few of the entries here that pertain to model rocketry. This thing is massive, and you'll want to get a copy for yourself. For information about this publication contact Bonnie@JPyro.com. Also, if you're ever thinking about writing for the Peak-of-Flight, this could be used as an idea generator. Take a topic, explain its importance, give background information and then take the subject even deeper. See Part 2 in Peak-of-Flight Newsletter issue 327 at: www.ApogeeRockets.com/Education/Downloads/Newsletter327.pdf}

Packing Fraction

Packing fraction is the ratio (or percentage) of occupied-space to void-space in a given volume of material. For example, when spheres of uniform diameter are packed into a container substantially larger than an individual sphere, approximately 74% of the total volume will be occupied by the spheres, and 74% or 0.74 is the packing fraction. In this case, the voids between and around the spheres will consist of approximately 26% of the total volume.

One way to fill a larger portion of a volume with particles is to use material with a range of particle sizes. In this way, the medium-size particles can occupy the space between the larger particles, and the smallest particles can

occupy some of the remaining void spaces. For example, in compounding highperformance composite rocket propellants, it is common to use three different particle sizes of ammonium perchlorate to increase its final packing fraction to approximately 90%. Such a deliberate mixture of particle sizes may be described as a multimodal (or more specifically in this case, as a trimodal) particle distribution.

In air, assuming the density of air can be ignored, the packing fraction (f_p) of a powder can be determined by comparing the grain density (ρ_g) and bulk density (ρ_b) (see density) of the material:

$$f_p = \rho_b / \rho_g$$

Propellant Grain Geometry

Some of the grain geometries used in model and high-power rocketry are presented below.

end-burning grain – The simplest, although not particularly effective, geometry is an end-burning grain. In its simplest form, it is a rod formed either by casting the propellant directly in the motor casing (i.e., case-bonded) or in a liner (i.e., cartridge-bonded) for subsequent loading in the motor casing, as illustrated below. The casing or liner supports the propellant and also serves as an inhibitor to limit burning to the end of the grain. Thus, the grain burns from one end to the other (sometimes described as in a cigarette-like fashion).

An end-burning grain produces a lower thrust for a

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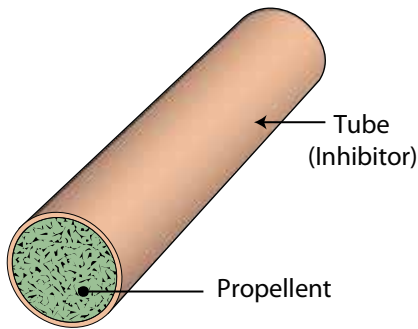
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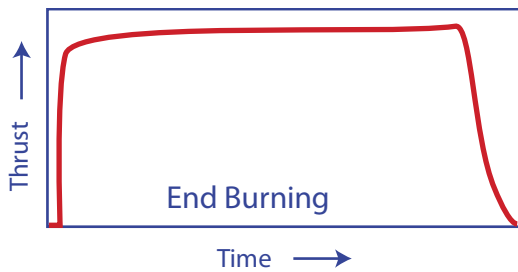
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Propellant Grain Geometry

much longer time, and allows the maximum amount of propellant to be loaded into a motor or liner, since there is no lost space due to a core or slot. End-burning, case-loaded grains also subject the motor casing to propellant heating effects for a long period of time.

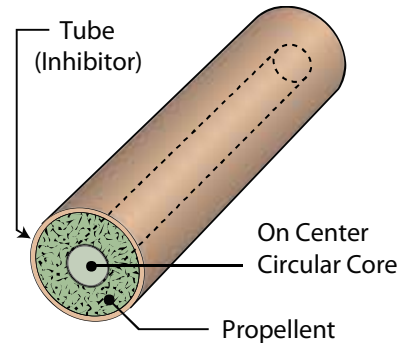


An end-burning grain produces a nearly neutral thrust profile, as illustrated below, possibly with a slight increase in thrust due to heating of the propellant and its casing as the grain burns.

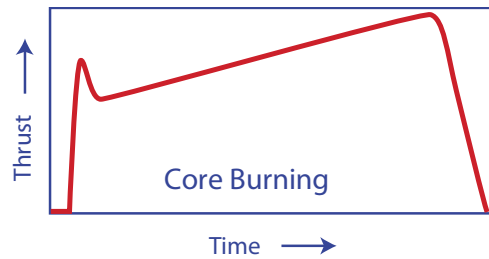


Core-burning grain – The first geometry used by composite, amateur rocket motors was a single, core-burning grain. In its simplest form, it is a thick-walled tube, formed either by casting the propellant directly in the motor casing

(i.e., case-bonded) or in a liner (i.e., cartridge-bonded) for subsequent loading into the motor casing, as illustrated at right. A mandrel is used to form the core during casting or is produced by drilling a core after curing the propellant. The casing or liner supports the propellant and also serves as an inhibitor to limit burning to the grain's core and ends.



The thrust profile is normally quite progressive, as illustrated below; this limits the chamber pressure range available to the rocket motor designer. If the initial chamber pressure is too low, combustion instability (e.g., chuffing) can be a problem. If peak pressure is too high, motor reliability suffers.



The initial spike in thrust (described as an ignition spike) is the result of short term erosive burning.

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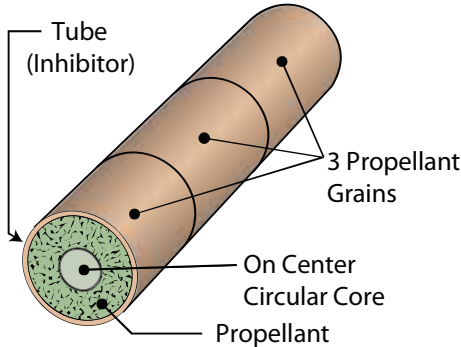
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PEAK OF FLIGHT

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Propellant Grain Geometry

BATES grain – (Acronym for BALListic Test Evaluation and System) – A test-system grain geometry developed as the forerunner of the US Air Force Rocket Propulsion Laboratory (Edwards Air Force Base) to provide a near-neutral thrust profile and provide an estimate of full-scale motor performance using a minimum of propellant.

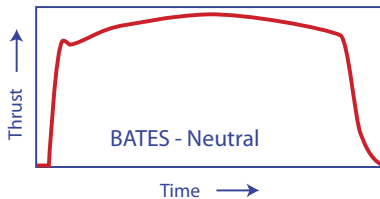


In amateur rocketry, BATES grains break the single, long, core-burning grain into two or more shorter grains that are often separated by short spacers (e.g., O-rings). For simplicity, in the illustration above, the internal core features of the BATES grain limits the operating rocket motor chamber pressure range to more acceptable values. It allows initial pressures to be high enough to prevent chuffing and yet limits peak pressures to lower values, which improves the overall reliability without unnecessarily raising motor weight. The core diameter still needs to be considered to limit erosive burning.

For an approximately neutral-burning motor, as illustrated below, the length of each grain (L) is adjusted to equal:

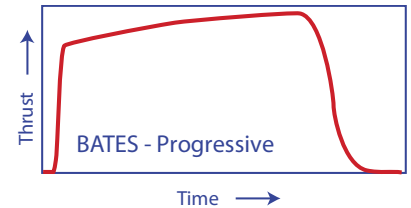
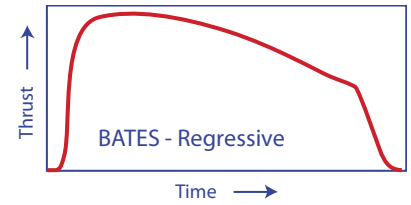
$$L = [(3 \times OD) + ID] / 2$$

Here, OD is the outside diameter of the propellant grain and ID is the core diameter.



For a regressive

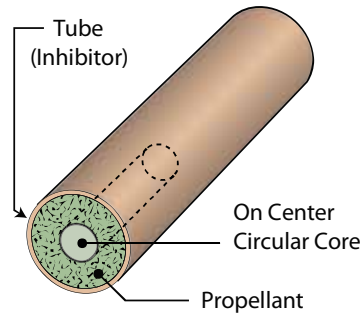
thrust curve, the length of the grains are made shorter than the above value (L); for a progressive thrust curve, the length of the grains are made longer than this value. BATES thrust profiles for typical regressive and progressive grains are illustrated to the right.



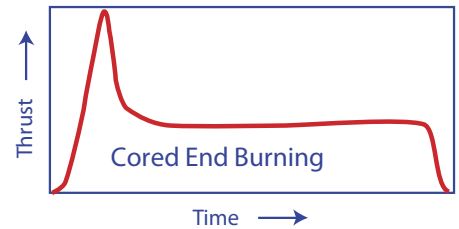
Cored, end-

burning grain – The grain geometry used in most Black Powder model rocket motors. Typically, the core is short and provides more initial burn area, both to facilitate ignition and to provide a higher initial thrust (that increases liftoff velocity to stabilize the rocket more quickly) than a simple

end-burning grain. This geometry is also sometimes used in composite motors for use with glider designs. The composite core is sometimes approximated by a cone or a short slot (not shown in the illustration shown to the left).



An example of a thrust profile for a cored, end-burning is illustrated here to the right.



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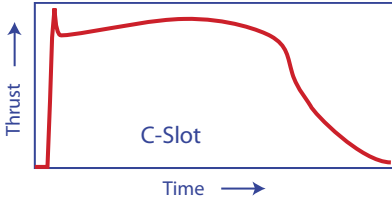
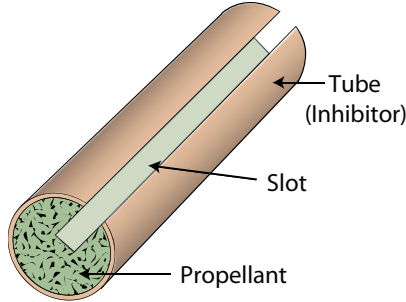
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Propellant Grain Geometry

C-slot grain – A single propellant grain that has a longitudinal slot cut its full length, as illustrated below. The depth of the slot is usually equal to the grain radius.

C-slot geometry produces an approximation to neutral burning, as illustrated below, by allowing a single grain to be used in a motor without the large rise in chamber pressure that would be produced if a core burning grain were used.



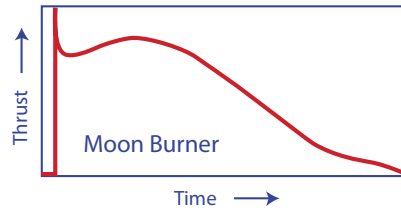
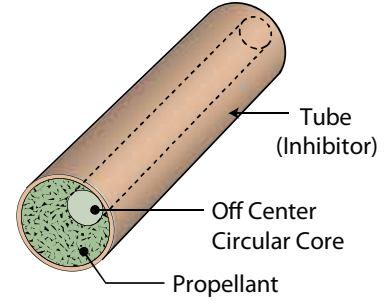
The initial spike in thrust (described as an ignition spike) is the result of short term erosive burning. The slot width and depth must be adjusted to

keep erosive burning effects within acceptable limits. A disadvantage of the C-slot is exposing a portion of the liner and casing to the high chamber temperature for most of the rocket motor's burn time.

Moon-burner propellant grain – A single propellant grain that has a core either tangent to the outer diameter of the grain, as illustrated in the upper right, or slightly

offset from it. The grain geometry is so-named because of the crescent (moon) shaped burn surface produced during its burning.

With the core tangent to the outer diameter of the grain and with the core diameter sufficiently large, peak thrust occurs immediately upon ignition. With the core moved toward the center of the grain and with a smaller core diameter, peak thrust is delayed until later in the burning of the grain, as illustrated below.



The initial spike in thrust (described as an ignition spike) is the result of short term erosive burning.

The web thickness and burning time is greater for the moon burner (or the C-slot grain if the slot depth is less than the grain radius) than for other cored geometries. The moon burner usually produces a thrust profile with longer tail-off than most other geometries. Moon burners share the casing heating characteristic of the C-slot geometry.

Finocyl grain – (Abbreviation for fins-on-cylinder) – (Also semi-star geometry) – A grain geometry that has a

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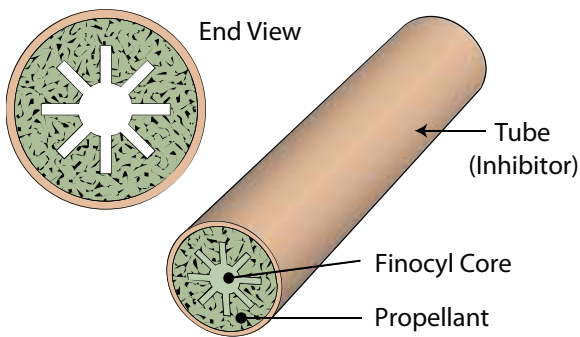
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Penny shown for size comparison

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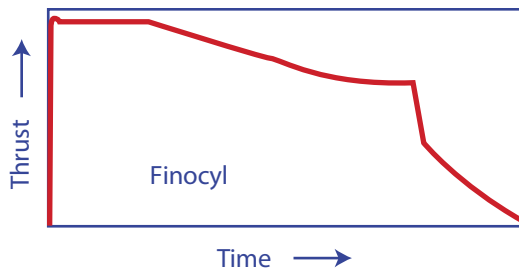
Propellant Grain Geometry



circular core with a number of straight slots (typically 4 to 8) extending out from the core's periphery some distance into the propellant, as illustrated below.

Finocyl geometry is used as a substitute for star core geometries because of the relative ease in making a mandrel for the core. (An alternative is to manually cut the slots into the propellant of a grain having a circular core after the initial grain has cured.)

The burning of a finocyl grain produces relatively high levels of thrust at the expense of being of relatively short duration, as illustrated below. It is a good choice of geometry for a case-bonded motor that requires nearly neutral burning and that needs to protect the inner wall of the casing from combustion gases until nearly the last moments of web regression.



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