ISSUE 49

APOGEE

PEAK OF FLIGHT

NEWSLETTER

Composite Propellant Booster Motors?

By Tim Van Milligan

The biggest booster motor available today is the D12-0. Occasionally, I'm asked why there isn't a big composite propellant booster stage motor.

A "Booster Stage" motor has the designation of a zero second delay. This means it fires its ejection charge immediately after the propellant is fully consumed (burn-out).

In a black powder propellant booster motor, there really isn't any ejection charge. What happens is that at the end of the burn, the propellant erupts forward and acts like an ejection charge. The hot gases inside the motor fly forward and ignite the upper stage motor.

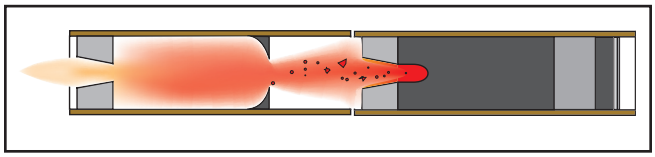

Figure 1: In black powder motors, the Booster stage ignites the upper stage directly.

The big advantage of a "booster" motor is that it greatly simplifies staging. You can use the hot gases of the lower stage to ignite the top stage motor. It doesn't' require special electronics on board the rocket to ignite the upper stage.

Note: You can get more information about staging black powder motors in Newsletter 98 and Newsletter 99.

The reason I get the question about composite propellant booster motors is that folks like the simplicity of direct staging without onboard electronics.

There is a problem with composite motors. That is, they have a forward bulkhead (some people call it the "forward enclosure").

You must remember, the rocket motor operates similar to a toy rubber balloon. The balloon needs a shell to hold the air, so that the pressure inside can only escape out in one direction: through the nozzle. In a rocket, the sides of the case and the bulkhead at the front are used to contain the gases inside - so they can be directed out the nozzle.

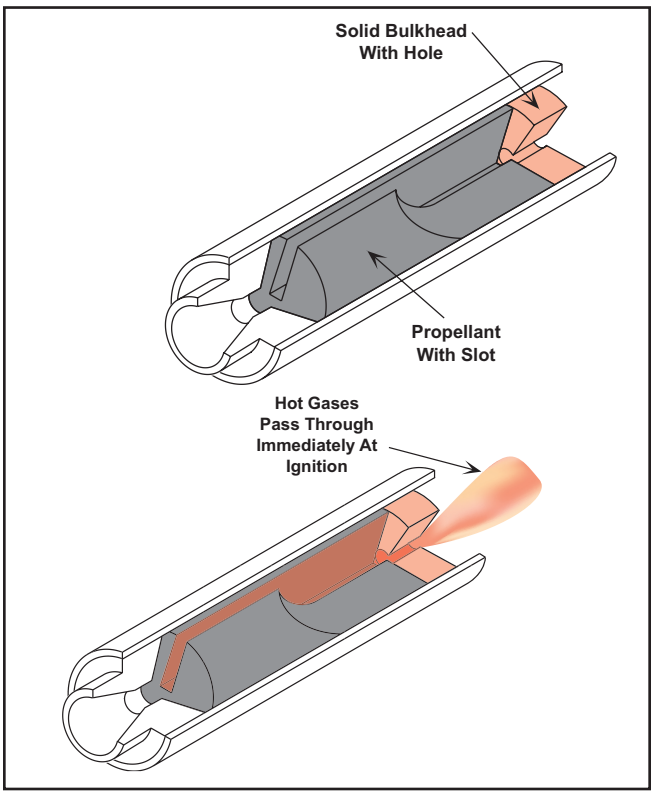

Figure 2: A composite motor needs a solid bulkhead. But a hole in the bulkhead would allow gasses through too soon in the flight.

Why don't black powder motors need a solid bulkhead in front like composite propellant motors?

The reason is that most composite motors have a hole down the center of them. The unfortunate thing about this hole is that it would allow the hot gases to immediately get to the upper stage motor; long before the propellant burned completely.

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In a black powder motor, motor doesn't need a hole in the middle, so the propellant at the front of the motor acts a bulkhead.

The next logical question is: why do composite motors need a hole down the center? Why can't they be end-burning motors like black powder propellants.

The key is that black powder has a fast burn rate compared to composite motors.

In order to produce sufficient thrust in the motor, you need a lot of hot gases inside the motor. That means a lot of propellant has to be burned quickly. A black-powder motor burns fast enough to produce this thrust just by burning the back end of the motor.

But in a composite motor, the propellant doesn't burn quickly enough to generate the gas particles needed to produce a lot of thrust. So to compensate for this, a hole down the middle of the propellant grain allows more surface area to be exposed. This then does allow enough particles to be converted to gas so that high thrust can be produced.

There are only a very few end burning composite motors available. They are the Apogee C4, Apogee D3, Apogee E6, and Apogee F10 motors. These motors have very low thrust levels; and would not make suitable "booster" motors. A booster motor needs high thrust to lift the weight of other motors (which are pretty heavy).

There is one more logical question you are probably thinking of: "couldn't you put a delay grain on top of the composite propellant grain?" The logic is that the hole down the middle of the propellant grain wouldn't hurt so bad. The delay grain would burn slow enough to allow the propellant to completely burn up before the gases burst through the top.

This is a really good assumption. But it has a flaw that makes it somewhat impractical.

The delay grain is similar to the composite propellant grain. If you ever put together a reloadable motor, you know what I'm talking about. Both the delay and the propellant are rubbery. The drawback of this is that the can't be used as a structural bulkhead.

The delay grain would probably burst through long before the propellant had done burning. The best we would be able to hope for (on a consistent basis) would be a very short delay before burn through.

In black powder motors, the propellant is also hard and strong. So it can contain the pressure in the motor; right up to the burn through of the last bit of burn time.

Fortunately, with bigger motors, there is so much thrust available that carrying an onboard ignition system is an option. The good news is that using electronic systems, there are features built into them to make staging reliable and safe.

One of the big concerns is that the rocket would stage at the wrong time. For example, if the rocket arced over and was headed horizontally, or worse: downward -- we wouldn't want the upper stage to ignite.

The electronic systems are able to detect a lot of events that would prevent such a catastrophe. First, it could detect if a certain G-force level was reached; and more importantly -- maintained for a certain amount of time. This would indicate the booster stage had fully burned, and not just catoed.

Then the electronic system could detect the negative acceleration of the rocket -- indicating the propellant had been fully consumed in the booster stage.

The electronic system could also determine if the rocket was still moving upward (using a barometric sensor). If it had arced over, this would tell the system to fire the parachute instead of the second stage.

For even greater safety or for achieving maximum altitude, you could create a onboard system that was looking for a certain acceleration curve (feed into it from a RockSim simulation). It would compare this curve against the measured acceleration. This would tell the system that the rocket was traveling straight up, instead of veering off at some angle.

In conclusion, when staging bigger rockets, an onboard ignition system does have its advantages. Unfortunately, it still doesn't eliminate the complexity.

About the Author:

Tim Van Milligan is the owner of Apogee Components (http://www.apogeerockets.com) and the curator of the rocketry education web site: http://www.apogeerockets.com/education. He is also the author of the books: "*Model Rocket Design and Construction*," "*69 Simple Science Fair Projects with Model Rockets: Aeronautics*" and publisher of the FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site, or sending an email to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.

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