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NEWSLETTER

Run Water Rocket Simulations Using RockSim

Designing water rockets has never been more fun and interesting than when you combine it with the RockSim software.

Advanced Design Tips for RockSim v8

Learn how to set up a ducted-rocket where the air flows inside the model.

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Running Water-Rocket Simulations in RockSim

By Tim Van Milligan

Attention school teachers: are you looking for some ideas and experiments you can do with water rockets? This article will give you a number of exercises that you can use with your students; from simple ideas, to some pretty advanced projects that could help you win in water rocket altitude competitions. Even if you are not a teacher, you might find this article useful if you do fly water rockets.

Every once in a while someone asks me if RockSim can simulate a pop bottle water rocket. The simple answer is yes, it can! And it is a very powerful tool if you want to optimize your design for peak altitude.

Designing the water rocket in RockSim is relatively trivial. It is just a matter of arranging the parts in the correct orientation. A simple water rocket based on a 2-liter pop bottle is shown in Figure 1.

Figure 1: A simple water rocket design created in RockSim.

By the way, as you start playing with the design, you will notice how extremely unstable these rockets are. Especially once you add water to them. You will have to do some work to get them to be stable, which is a good exercise for students. I don't know of any other program available that can help you turn an unstable water rocket into a stable one. If you or your school does not have RockSim yet, this would be a good time to buy it.

The hard part is running a simulation. The reason it is hard is because RockSim does not predict the thrust of the rocket. Maybe one day it will, but right now, it doesn't. RockSim needs information about the propulsion system in the form of an engine file.

I did a web search on the internet and found a number of online calculators that will determine how high a water rocket will go. They are pretty simple to use, if you know the dimensions of your rocket and how much water you'll be putting into it. The one that I found most useful is located at: http://cjh.polyplex.org/rockets/simulation/

The reason it is the most useful is because it generates a thrust curve for the simulation. Other than that, I'd take RockSim's results over its flight simulations because you get a lot more information from RockSim and you can see what the trajectory will look like in the 2D flight profile.

But to run your simulations in RockSim, you will need that thrust curve, because you will use that to create an engine data file.

What you'll get from the water rocket web site is a thrust curve that looks like Figure 2.

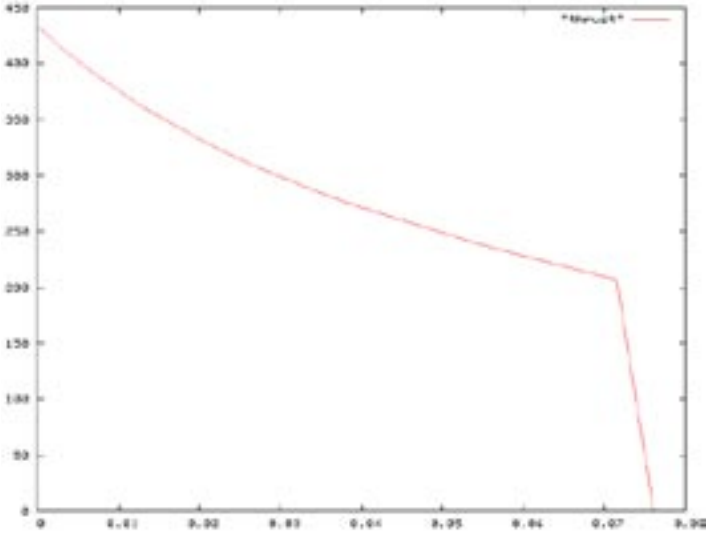

Figure 2: Thrust curve generated by one of the free online water rocket calculators.

To turn this into an engine file, we'll use a free little program from John Coker's www.thrustcurve.org web site. The program is called TCtracer, which stands for "Thrust Curve Tracer," and can be downloaded for Windows and Macintosh at: www.thrustcurve.org/tctracer.shtml.

Basically what TCtracer does is allow you to trace the curve by clicking points on the graph, and it will generate an engine file that RockSim can read. I previously made a movie on how to use this program for entering motor data from Tripoli data sheets. The process is nearly identical.

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Please watch the video on the Apogee Components web site at: http://www.apogeerockets.com/education/downloads/Tripoli_Motor_data.mov

The only thing that I'd like to add at this point is that I've made a new quicktime movie that describes how to take a screen shot of your computer screen and turn it into a jpg image. TCtracer only recognizes jpg images, so unless you are able to do this step, you'll be stuck. That new video is at: http://www.apogeerockets.com/education/downloads/Make_a_jpg.mov

When you use TCtracer, you should end up with something similar to that shown in Figure 3.

One note about the TCtracer program. You have to get a green checkmark at the bottom of the screen before you can continue on. If you don't get that green checkmark, try moving the first point on the thrust curve a little to the right. I found that if it is too close to zero seconds that it will give you an error.

The last part prior to saving the engine file is to enter the motor information. It is at this point that you'll have to put on your thinking cap in order to fill in some of the blanks. The motor information screen looks like Figure 4.

I recommend you make the diameter 18mm, and the length approximately 180 mm long. The length can be tweaked later after you know how high it is in your water

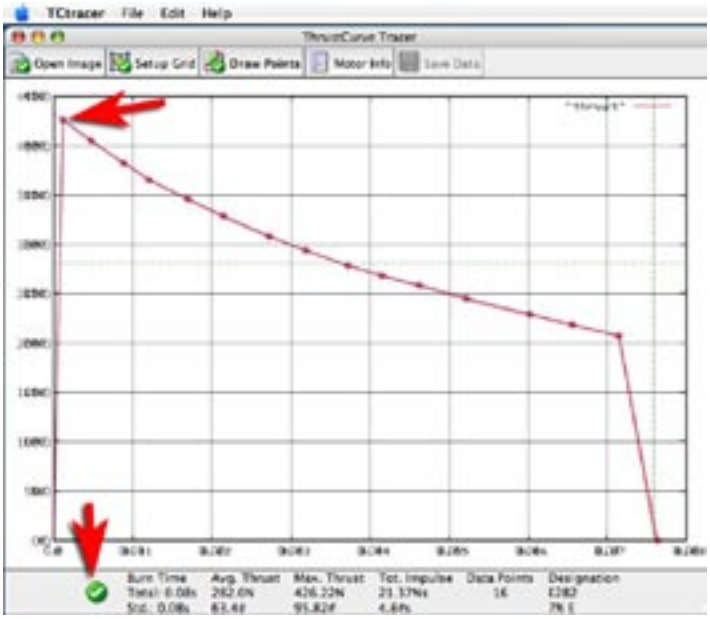

Figure 3: TCtracer allows you to trace a thrust curve to make your own motor file. Make sure that the first point on the curve is not too close to the Y-axis, or you will not get the "all-is-clear" green check mark.

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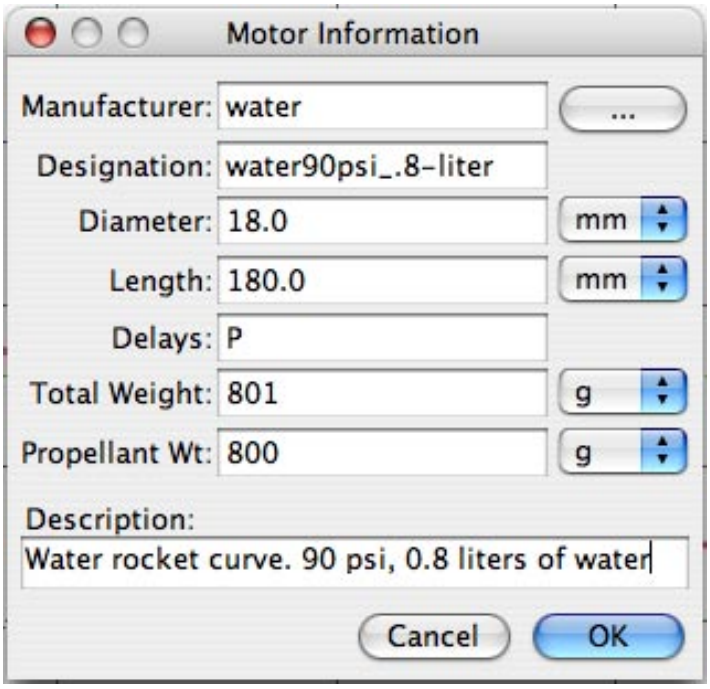

Figure 4: The motor information panel from the TCtracer software. Use a "P" for a plugged motor.

rocket. But 180mm is a good guess for about 800ml of water.

Determine the propellant weight next. Since water has a density of 1 gram/ml, we know that 800 ml will have a mass of 800 g. That is your propellant weight.

The total weight in TCtracer must be greater than the propellant weight, which is why I say to make it 1.0 grams more. So if your propellant weight is 800 grams, make your Total Weight 801 grams. We can fix this later in the Engine-Edit program that comes with RockSim.

I also recommend putting a description of the conditions that made the thrust curve in the description field. Be sure to list how much water, and how much air pressure was used. This will help you keep things straight when you start making multiple engine files later.

At this point, save the engine data file. I recommend saving it in the "Data" folder of RockSim, where all your other motor files are stored.

You can jump right into RockSim and get ready to run your simulations at this point. The only other preparation you need to do is to reload the engines from the "File" pull-down menu in RockSim.

Then create your water rocket design, load your motor and start running simulations. Well… that does take some time to create your rocket design, but you know how to make rockets in RockSim at this point.

If you are a teacher and want a sample design file to use that will save you some time, I've created a sample bottle without the fins, as shown in Figure 5. Your students can create their own fins and make sure their rocket is stable and get it ready to launch. But before adding fins, remember to load the new engine into the water rocket so that the CG is in the aft-most position.

Figure 5: Download a RockSim design file for a 2-liter water rocket. Just add your fins, some nose weight, and your engine file.

Download this water rocket design file for RockSim from the Apogee Components web site at: www.ApogeeRockets.com/education/downloads/water-rocket.zip

What kinds of things can you do at this point?

You've already accomplished a huge amount to get to this stage in the process. So first sit back and give yourself a pat on the back.

1. You've generated data on the water rocket web site.

2. You've taken a screen shot from your computer and turned it into a jpg image.

3. You've downloaded and installed the TCtracer software and have set it up. Then you've used it to trace the thrust curve.

4. You've calculated the weight of the rocket fuel (water) by measuring its volume.

5. You've created a stable rocket design using a pop bottle for the body.

6. You've loaded the engine into RockSim and run your first flight simulation.

Here are some other things you can do for water rocket experiments.

First, go back to the water rocket web site and create some additional thrust curves utilizing different conditions. For example, vary the amount of water in the rocket, and

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then vary the air pressure in the bottle. On that web site, you can get a general idea by looking at the online simulations what the optimum amount of water and air to use by the altitude of the rocket. When you get that rocket to the highest altitude, you're probably at a good combination of water and air. But as a teacher, you might want to limit the amount of air pressure in the bottle (for safety reasons). A good research project for the students is to do a web search and find the bursting pressure of a pop bottle.

Once you find a good optimum water and air ratio, go ahead and generate a new thrust curve for use in RockSim using the procedures described previously. Then rerun your simulations and see how things have changed.

You can then do a whole host of experiments with water rockets by running the same kinds of projects you'd do with normal model rockets. You can do things like:

1. Run optimum mass predictions using RockSim to figure out what mass you can add to the rocket to get the best altitude. None of the online water rocket calculators do optimum mass prediction like RockSim, and I think the results will surprise you. (See *Peak-of-Flight Newsletter #200* at www.ApogeeRockets.com/education/downloads/Newsletter200.pdf for more information on performing optimum mass calculations using RockSim).

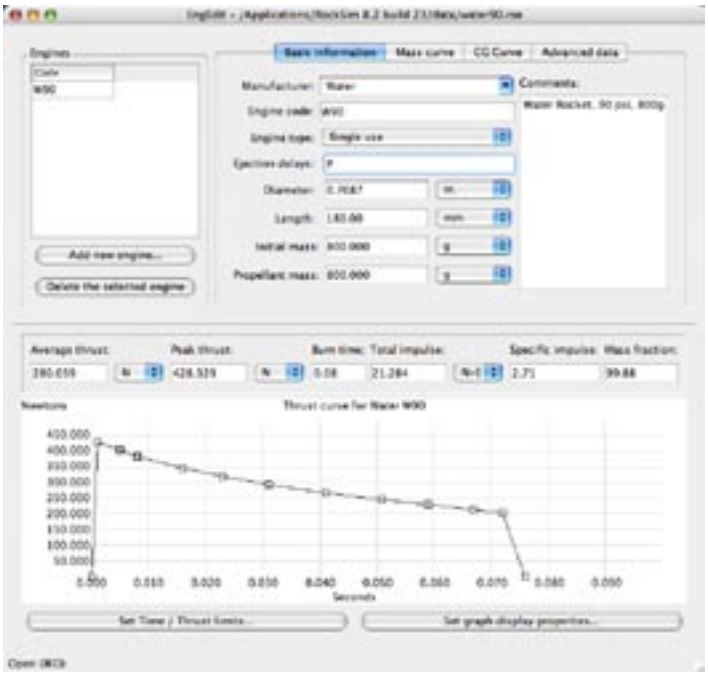

Figure 6: The Engine Edit software that comes bundled with RockSim will allow you to refine the engine file for maximum accuracy.

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2. Vary the placement of the fins and see how that affects the CP position. RockSim's ability to see the changes in the CP and CG locations make it an ideal tool to use to design stable water rockets. It is much better than finding the "center of lateral area" (also called the cardboard cutout method) that online water rocket calculator sites recommend.

Once you get things dialed in, now you can start tweaking your files to get even more accurate information from RockSim. For example, remember when we said that the TCtracer program requires the Total Weight to be greater than the propellant weight? We can get rid of this limitation by opening the engine file created by TCtracer in the Engine-Editor program that comes bundled with RockSim (see Figure 6).

The Engine Edit program will allow you to have the same initial mass as the propellant mass.

The other thing you can do in the Engine Edit program, if you want even more accuracy, is to create a CG-shift curve for the motor file. Click on the CG curve tab at the top of the screen to create a CG curve.

Normally, RockSim assumes the CG of the engine stays in about the same spot during the burn of the motor. But this is not true with a water rocket. Water rockets are unique in that they are "top-end" burners. It is like the top surface is receding downward as the water flows through the nozzle. So the CG of the propellant moves rearward as the water is expelled out the nozzle.

The CG curve is then going to have a bell-shape to it,

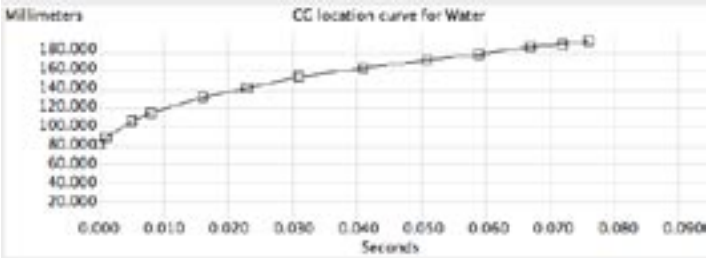

Figure 7: Approximate shape of the CG-versus-Time curve from a typical water rocket. It shows that the CG is moving aft as the water flows out the bottom of the bottle.

as shown in Figure 7.

I have to admit that creating a CG curve for the water rocket may be a bit overboard. The burn-time of a water rocket is so brief that I doubt that the rocket is going to react to a gust of wind (it is very heavy at lift-off and has a lot of inertia). And besides, the jet-damping is pretty significant, which will also keep the rocket on a straight trajectory (See *Peak-of-Flight Newsletter #195* at www.ApogeeRockets.com/education/downloads/Newsletter195.pdf for more information on jet damping). If the rocket is statically stable prior to launch, then it will remain stable during the flight.

If you are a teacher, you might have your students

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Water-Rocket Simulations in RockSim

make some other comparisons between model rockets and water rockets. For example you can compare:

1. Total Impulse of water versus model rocket motors. What is the equivalent size of rocket motor? Hint: You can find this information at the bottom of the screen in the TC-tracer software.

2. Burn time comparison: compare to an equivalent rocket motor (one that is listed on the Apogee Components web site).

3. What approximate altitude does a water rocket burn out? Again, compare this to an equivalent size rocket engine.

4. If you put an equivalent size rocket engine into a water rocket, how high would it fly?

5. Make a fictitious rocket engine file in the Engine Edit program. Take the water rocket thrust curve and only change the initial mass and the propellant mass. Match them to the equivalent rocket engine you selected previously (must be a real engine listed on the Apogee Components web site). Now run your launch simulation using that engine. How much higher does it go compared to the water rocket thrust curve?

6. Take the flight simulation that used the rocket and fictitious engine file from the previous step. Run an optimum mass calculation in RockSim. How much extra weight would you have to add/remove to the pop bottle? Is it the same optimum mass as the water rocket's optimum mass?

Conclusion

Creating water rockets into RockSim takes a little bit of extra effort, but it is worth it. You'll be able to see how much more efficient a model rocket engine is in comparison. A lot of power is packed into a tiny little casing.

From an educational standpoint, there are also a lot of benefits. You can run a lot of simulations in a short amount of time and make some excellent comparisons.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. Before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he 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 a FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site or by sending an e-mail to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.

How Many Flights?!

I was happy to have my favorite rocket, the Nordic Rocketry* Meanie, reach its 60th flight (actually 61st flight was completed as well). * No longer making rocket kits.

What's interesting about the Meanie is that it is not some super-duper high strength rocket that is built to be indestructible. Rather, quite the opposite. The body tube is paper (1/16" thick cardboard), its fins and centering rings are 1/16" laser-cut plywood, and its nose cone is balsa. The fins are surface mounted to the body tube.

There were two techniques used during the build that improved the strength. One was to use a T-pin to poke holes along both sides of the centerline where the fins attach. This is done to allow the glue to seep into these holes making the attachment of the fins to the body tube stronger. They act like little rivets!

The other technique was the attachment of the eye-screw to the nose cone. This is screwed, glued and bridged. Bridging where the glue is "bridged" through the eye-screw to increase its hold to the nose cone.

So, despite a CATO of an Estes D12 on the 3rd launch (which required the nose cone to be filled and re-painted), several other parachute deployment issues, and one descent that took nearly 8 minutes… this rocket has been a Meanie toward the skys. It has flown on 28 D's (D9, D10, D12, D15 and D21), 14 E's (E9, E11, E18, and E28), and 19 F's (F12, F24, and F39).

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RockSim Advanced Design Tips

How to Create a Ducted Rocket Design Using RockSim v8

By Tim Van Milligan

There was a recent thread on "The Rocketry Forum" that caught my eye. It was about creating a ducted rocket using RockSim (http://www.rocketryforum.com/showthread.php?t=48531).

Essentially, the nose cone was half-buried inside a larger diameter tube. The fins were then attached to the outside of the larger tube.

This kind of design was not on our minds when RockSim v8 came out a few years ago, so we did not really consider how one would model it in the software.

BrianC from Orlando, Florida decided to give it try. And what he came up with was pretty novel.

Basically what he did was create a nose cone, followed by a transition section (red in the 2D drawing). Attached to the base of the rocket is an outside body tube (blue). Around that tube, he put a ring tail fin (shown in green). He also added fins to that same body tube, but positioned them off the back end of the tube out in space. That's why the root edge is angled instead of being straight. They look like they are attached to the outside ring-tail fin, but they are not. If you look in the parts tree, they are attached to the blue tube.

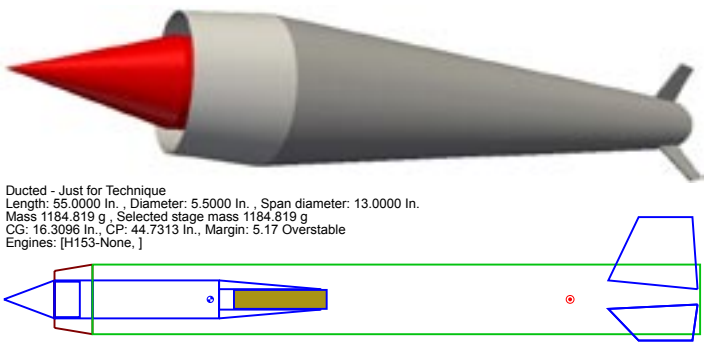

Figure 1: Ducted tube design created in RockSim v8.

The next question is whether or not this design will give realistic simulation results. My opinion is that it should be pretty close. The parts are all in the correct position on the model and the CP looks to be in the right spot too.

This is a good case study of the types of advanced rocket designs that you can make in RockSim v8. If you don't own a copy yet, you can always try our free trial version. You can get that from: www.ApogeeRockets.com/rocksim.asp.

If you want to see this particular ducted-rocket RockSim file, download it from: www.Apogeerockets.com/education/downloads/ducted.rkt.zip