PEAK OF FLIGHT NEWSLETTER

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PEAK OF FLIGHT

Drag On Differing Rocket Shapes

By Tim Van Milligan

As rocketeers, we've all wondered how to make our rockets more aerodynamic. For example, does making a small change to the shape really help, or is the effort not worth the expense and hassle it will take to implement the change? This is classic engineering. Whenever you make one change, it has effects in other places -- usually making the model more expensive. It is the evaluation of different trade-offs that makes rocketry fun and at the same time it can also be frustrating.

To make decisions about what shape to make the rocket, we use tools like RockSim. Unfortunately, sometimes the tool is limited, so we search for others that can help us see which shape will be better.

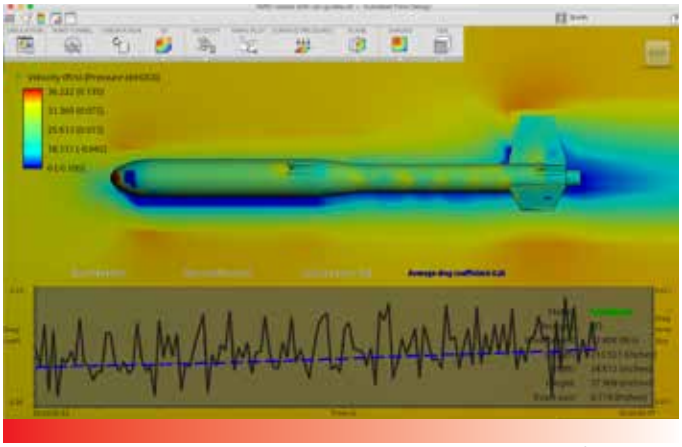

Figure 1: TARC style rocket in the Flow Design Software to analyze the drag and airflow about the model

I discovered a different tool in the last few months that I want to share with you. It started last year when a TARC team sent me a screenshot of a CFD analysis of their rocket design **(Figure 1)**. They were wondering how to interpret the results and to figure out why their rocket was going unstable.

The quick answer was that their fins were too small. This situation tends to occur when you have a very front heavy egg-lofter and you're trying to minimize the drag of the rocket. It also happens in long superroc style rockets, which are so long that the CG seems to be miles away in front of the CP. Modelers look at the stability margin, and conclude that the fins can be made tiny.

What this means is that the stability equations don't predict everything that is happening in a rocket flight. In this case it was a stability issue, but the most complex situation is determining the aerodynamic drag on a rocket. I've written extensively on this subject (see resources at the end of this article) in regards to getting the maximum simulation accuracy. In the end, you'll have to determine the drag coefficient with flight testing.

In Peak-of-Flight Newsletter 45, I mentioned that CFD software was another way to get information about your rocket. CFD stands for Computational Fluid Dynamics. That was what caught my eye when the TARC team approached me last year. They were using a CFD software tool that I didn't know existed.

When I had some time this winter, I explored the software that they were using. It was a CFD software called Flow Design.

The Flow Design software can be downloaded at: http://help.autodesk.com/view/ADSKFD/ENU. Autodesk has an educational policy that lets schools use this particular software for free. A nice addition to this policy is that if you mentor a student, you can also use the software for free. Since I mentor Team America Rocketry Championship (TARC) students, I took advantage of the free license to use the software. This is another great reason to pay it forward and help out with the TARC program (www.rocketcontest.org).

Flow Design is not AutoDesk's premier CFD simulation software. That honor goes to AutoDesk CFD (http://www.autodesk.com/products/cfd/overview). The unfortunate thing is that the license

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About this Newsletter

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to use AutoDesk CFD costs $7,000 per year, and they don't have a free educational version that I know of.

The one caveat about CFD software, is that in order to use it, you have to input a 3D model of the item you want to immerse in the virtual wind tunnel. Fortunately, Flow Design imports the .stl file formats, which is the same format used by 3D printers. So almost any Computer Aided Design (CAD) software can be used to generate the models. I personally use another Autodesk CAD product called "Fusion 360" (https://knowledge.autodesk.com/support/fusion-360). But almost any CAD program can be used to create the models.

I have to admit that there is a hurdle you have to surmount just to use the software. Learning CAD software, if you've never done it before, will take you a few weeks to a few months of effort. But because you have spatial awareness that comes from flying rockets, this should be easier for you than it might be for people without rocketry experience.

The web page where you download the software has some very good videos on how to set up the wind tunnel and make sure that you don't get interference from the walls. This is important because it can easily skew the results. It will probably take about an hour to go through the tutorial videos and get things dialed in.

Running a simulation can take 5 to 10 minutes because it is very processor intensive. On my computer, the fan comes on within 30 seconds as it chugs away at the calculations.

What the Software Is Good For and What it Can't Do:

The Flow Design software is good for finding the overall drag force of the rocket, and displaying surface pressure on the rocket, the speed of the air over different surfaces of the rocket, and the turbulent flow behind the rocket **(Figure 2)**.

What is doesn't do is to display the lift forces generated by the rocket, nor the Center-of-Pressure location of the vehicle. This is unfortunate, because you can't use it to compare CFD results of Flow Design versus the static stability equations of RockSim. The software does actually have all the data to compute this information, but the company that makes it wants users to upgrade to their other CFD software.

The software does display a Coefficient of Drag for the model, but you really can't use it for anything useful. For example, you can't take the

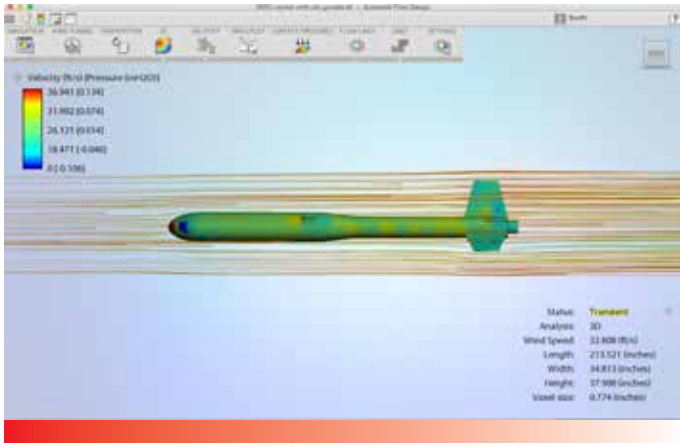

Figure 2: Seeing the air flow over the model can help you make improvements to it.

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number it gives and simply plug it into RockSim to get a better peak-altitude prediction. The reason is that we don't know what reference area it uses to come up with the Cd number. In RockSim, we use the diameter of the tube to calculate the reference area. But the Flow Design software is so versatile that it can use any shape rocket, even those with a square cross section. We don't know what it is actually using.

With this limitation, what it is useful for is this: to compare changes within a basic rocket design. For example, you might change the shape of the fins, modify the shape of the nose cone or add a boattail to a rocket, and compare it against the original design.

Again, don't expect the results to give you a number that you can plug into a program like RockSim. This is frustrating, I know. But if you know the limitations of what you can do with a tool, you will only use it for the one thing that it is good for.

The Main Screen:

The main screen of Flow Design shows a side view of the model in the wind tunnel. You'll notice right away how colorful the screen is. The purpose of this is to display a lot of information quickly.

The first is the area around the model. For example, in **Figure 3**, the area around the model is various shades of green and orange. The color represents the speed of the air flowing over the model. Using the color key on the left side of the screen, you can see the what speed the air is at any spot in the tunnel. Typically, the color furthest to the left is the speed you set for the simulation. Ideally, you want the entire area surrounding the model to have that same color. That would mean the rocket is slicing cleanly through the air.

Figure 3: The main screen of the Flow Design software

But the model affects the air. The air has to flow around the shape, and as it does it either speeds up or slows down. It will slow down directly in front of the rocket, and speed up as it flows around the front edge. And behind the model, it also slows down considerably.

When there is a lot of color change in a very small space, you can be assured that there will be a lot of turbulence of the air. This is bad, as it also indicates a higher amount of drag on the model.

Again, you want the color of the air around the model to be a uniform color, as that means drag will be low.

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The other color information is the color displayed on the model itself. This color is independant from the color of the air. It represents the surface pressure on the model. For example, a blue color in **Figure 1** represents a low surface pressure, and a orangish color would represent a high pressure.

This is where the drag force is calculated. Pressure is computed as a force per unit of area. So you can find force on the rocket by taking the pressure at any spot on the rocket and dividing it by a given amount of area. Summing up the forces in the X-direction will give you the overall drag force on the model. The software does not sum the forces in the Y-direction, which if it did, would give you the overall lift of the model in the wind tunnel. I wish it did, but it doesn't…

You can also display a drag plot for the model. This is used only to see how far along the software is in calculating the flow of air around the rocket. The flow has to stabilize in order to get a good calculation of drag, and this takes some time. You can watch the drag plot fluctuate wildly when you first start a simulation, and eventually it will settle down to a very narrow range. When it does, the display on the right side will indicate that the flow has stabilized. When it is stabilized, you can finally use the results from the simulation.

The other really useful thing you can do with the software is to have it display the flow lines around the rocket **(Figure 4)**. Think of this as tracking a single particle of air, and watching it flow past the model. If the particle moves in a straight line, that is a good indication of low drag. There is also color information displayed too in the tail of the flow line. The more reddish the color, the faster the particle is moving. It if gets into the bluish range, that means the particle has slowed down. Again, you want a constant color over the entire path of the particle, and having it follow a straight line.

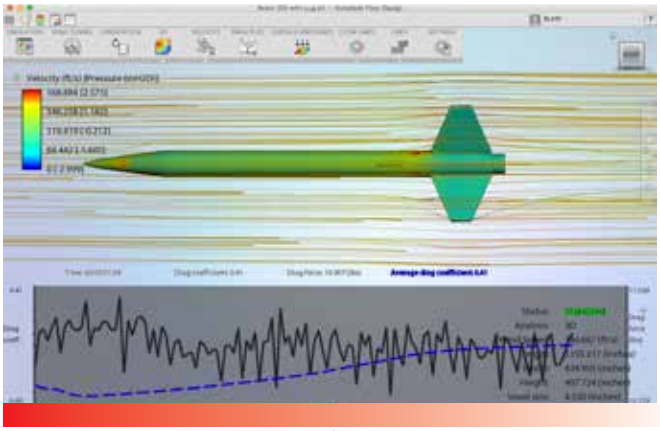

Figure 4: Visualizing the airflow over the rocket helps you see where mixing occurs.

Since the software is full 3D, you can view the flow from a lot of different directions. This really helps you watch the flow in various areas of the rocket. You can also compress the flow lines to just a small column, so you can isolate the flow to a specific area over the rocket. This really helps because it eliminates a lot of the flow in areas you don't care about. It is like looking through a cloud of smoke at a specific area of the model. If you move the smoke further away from the model, you can more clearly see what is happening next to the model's surface.

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Drag on a Rocket

What I used it for the first time I tried it was to see what happens to the drag when you add launch lugs and rail buttons of various sizes to the rocket. Since the components are so small, I had to enlarge them 10 times their normal size in order for them to generate enough of a force where the software could distinguish the added drag **(Figure 5)**.

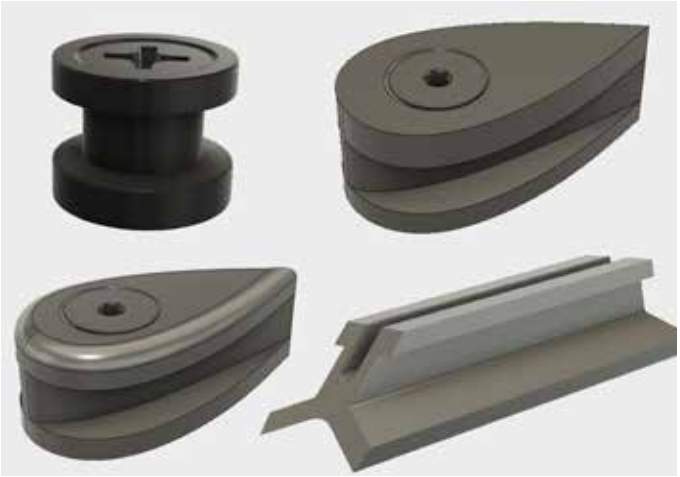

Figure 5: With Flow Design, you can test individual parts like the differences between rail buttons and rail guides.

What I found out was completely unexpected. If you can believe the results of the simulations, those small little rail buttons have a lot of drag. They produce more drag than a standard ¼" diameter launch lug, and even more drag than a larger rail guide.

I also wanted to see how much drag those airfoil rail buttons have in comparison to a standard rail button. It turns out that they do help reduce drag, by about 37%. And if you take some sandpaper and round off the leading edge, the drag is about half that of a standard rail button.

If you want to see what I did, the R&D report of the drag of launch lugs, rail buttons and rail guides can be found on the Apogee web site (see the resources at the end of the article).

Conclusion:

The Flow Design software is a cool tool that you can use to experiment with, to find out some of the answers to those questions you have about making your rocket fly better. It doesn't answer all of them, but it gives some great insight to what is happening with the flow of the air around the rocket.

You do have to create the 3D model of your rocket (sorry… RockSim doesn't export a 3D design either). That is the challenge to using the software. But if you want a few models to experiment with, there is a zip file with a few designs that should load easily into the Flow Design Software so you can try it out.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor, and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the

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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 also the author of the books: Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at: https://www.apogeerockets.com/Contact.

Resources:

Drag of Launch Lugs, Rail Buttons, and Rail Guides - https://www.ApogeeRockets.com/downloads/PDFs/launch-lug-drag.pdf

Maximum Simulation Accuracy - Part 1 https://www.apogeerockets.com/education/downloads/Newsletter45.pdf

How To Determine The Drag Coefficient of Your Rockets https://www.apogeerockets.com/education/downloads/Newsletter303.pdf

Some 3D test models (.STL format) that will work in Flow Design - https://www.apogeerockets.com/downloads/3D-Flow-Design-Models.zip