Understanding Rocket Stability Part 2 – Centre of Pressure

Learning Objective	In a part one we introduced the concept of rocket stability. We also discussed the centre of gravity, or CG, and how it can be found both physically and through the use of the program OpenRocket. In this lesson we will expand on rocket stability by focussing on the centre of pressure or the CP of a rocket.
Grade Level	9 – 11

– Introduction –

Figure 1 -Homemade weather vane

Imagine if you will a long tube balanced in the centre or CG on a pivot. If we were to apply a steady air stream directly to the pivot point the tube would not rotate as there would be equal

force applied to both sides of the tube.

If we were then to add a piece of flat cardboard to the one end of the tube, then find the new centre of gravity and balance the tube, something interesting happens. Our air stream now pushes against the flat cardboard and causes the tube to rotate. The end with the cardboard piece is now pointed in the opposite direction of the air stream.

What we have created is a good old fashioned weather vane. Figure 1 shows a simple weather vane made with cardboard and a straw to demonstrate this concept.

Centre of Pressure

Why did adding a piece of cardboard to the tube suddenly cause this rotation? What we have essentially done when we added the cardboard was change the centre of pressure (CP). An object such as a weather vane will rotate along its centre of pressure when air flow or wind is introduced.

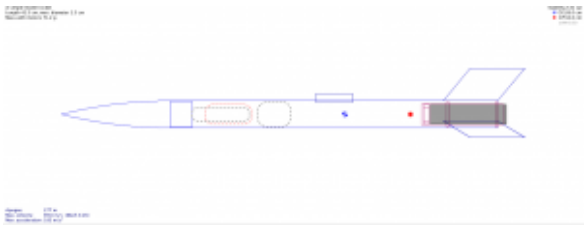

Figure 2- OpenRocket Example Rocket

Without the cardboard piece the centre of pressure equals centre of gravity and thus the tube (in our example, a straw) does not rotate when a direct flow of air is introduced. This concept of centre of pressure is very important in rocket flight.

You may see an example of a rocket design in figure 2. If the CP is ahead of the CG (in relation to the nose cone) the rocket

will not be stable in its flight.

You can visualize this by imagining a gust of wind hitting the rocket sideways on its way up. The wind will force the rocket to swivel along the CP, however, the thrust of the rocket upwards will balance out this force as the rocket will swivel on its CG. A good rule of thumb is to have the CP the distance of a body diameter or more behind the CG.

Finding the Centre of Pressure

An old trick to finding the CP of a model rocket is to trace a profile of the rocket onto cardboard, cut the profile out and then balance this profile on a pencil or pen. The balance point will be the CP. This is quite logical if you think about it because a sideways wind hitting the rocket on its way up acts upon the profile of the rocket.

In 1966, James S. Barrowman, an aeronautical engineer at NASA, came up with a simplified method for calculating the centre of pressure of a model rocket. Barrowman's calculations are used in rocket design and flight simulation software such as OpenRocket.

Another way to determine CP is to use these simplified calculations on this web page from the NASA web site.

We will use OpenRocket to determine CP for the rest of this article.

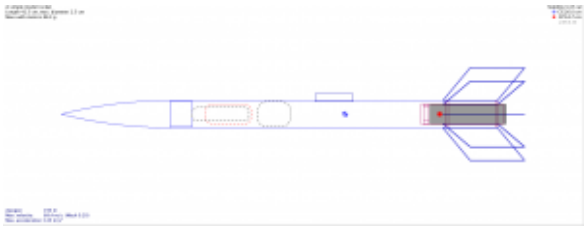

Figure 3 – Rocket design after changes

Changing the Centre of Pressure

If you do not have a copy of OpenRocket you may download one by clicking on this link. From the file menu of OpenRocket you may open up the example rocket by selecting Open example. Figure 2 shows the sample rocket.

You may observe in figure 2 that the CG is 26 cm from the nose cone and the CP is 32 cm from the nose cone (you may have to click on the picture to see this information). Having the CG ahead of the CP means that this design is a stable one.

Let's now change the CG of the design. We can change the weight of the nose cone by clicking on Nose cone | Override | Override mass. For our example we add 20 grams to the Override mass value. Now if we look at our CG value it is 24 cm instead of 26 cm. The CP did not change.

To change the CP lets add fins to our design. Double click on Trapezoidal fin set to open up the fin configuration. Change the Number of fins value to 8. The CP of our rocket is now 34.7 cm. Figure 3 shows our new design.

Suggested Reading

The following is a list of some of the resources used in the writing of this article:

1. Handbook of Model Rocketry by G. Harry Stine and Bill Stine.
2. OpenRocket technical documentation by Sampo Niskanen.
3. Model Rocket Stability by Rick Weber