Modeling the Wind Blocking on a Space Tether

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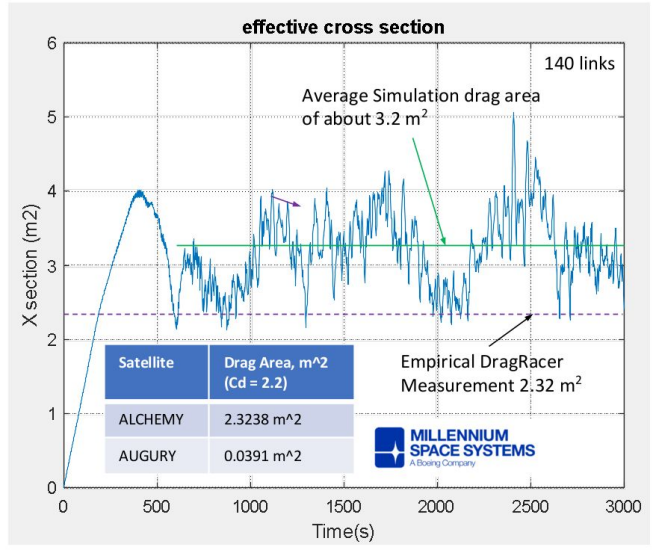
Introduction: The Dragracer experiment

The dragracer experiment studied the deorbiting of two cubesats. One with a long ribbon like space tether attached to it, Augury, and one without a space tether, Alchemy.
Analysing and tracking these two satellites the effective drag produced was obtained. This value is compared to the expected effective drag obtained from the stimulation of a cubesat with a space tether.

Results From the Dragracer Experiment

The obtained effective drag is 40 % lower than the effective drag predicted by the stimulation.



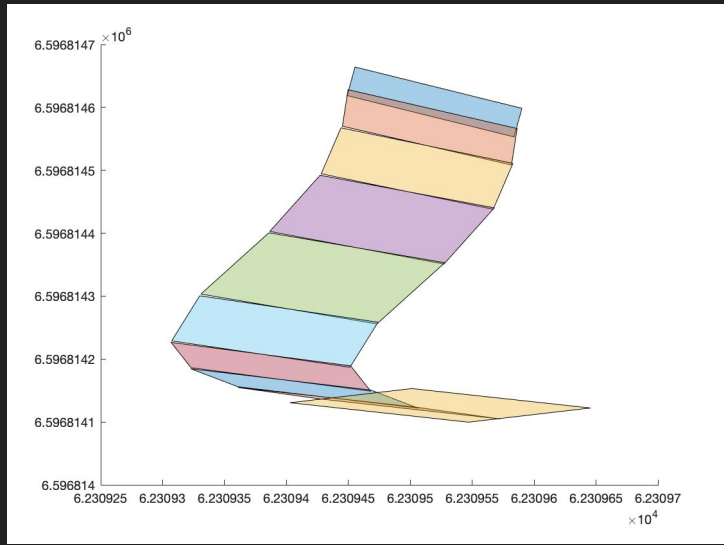
One of the possible reasons behind this difference is that as the space tether flutters through space the links that are along the upstream direction could possible be blocking the downstream links resulting in a lower effective cross section area.

The purpose of the research is to come up with a function that calculates the fraction of each link that is being blocked by the other upstream links at any given instance (i.e. at any position). This function would then be integrated into the stimulation model.

Outline of The Wind Blocking Model

The wind blocking model has two main parts:

- The first part determines the right coordinate system (the wind coordinates i.e. the direction of the wind is considered to be the positive x-axis) and then using the coordinates for each link in the new coordinate system it plots a 2D projection of all the upstream links in the y-z plane. (The function does not print out a 2D plot at ever instance. The 2D projection data and other needed information for each link is stored in a object class called “link” it uses the inbuilt Matlab polyshape object to perform calculations)
- The second part of the model uses the 2D plot to calculate the fraction of the area of each link that is being blocked by the other links.

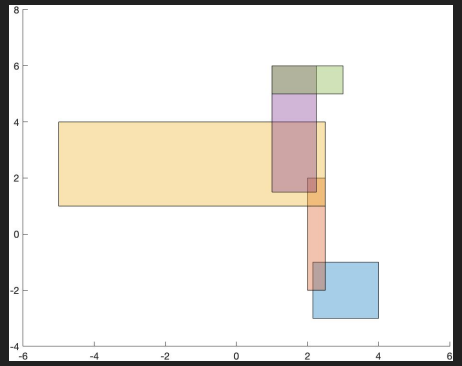


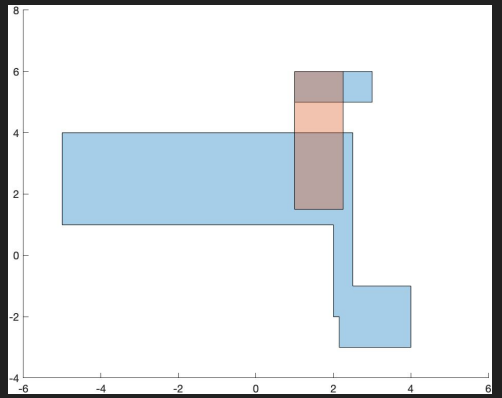
This is how a tether with 10 links looks like at a random instance

Working of The Main Function

The following is a simple test case that was used to test the working of the second part (blocking area calculation part) of the wind model.

1. The first figure shows rectangles that are stacked on top of each other. The ones in the back have a darker shade in the covered region.
2. We look at the fraction of the purple rectangle that is blocked by all the other rectangles collectively.
3. In order to find the blocking area the function first plots a polygon that is the union of all the polygons except for the purple one. The image to the right shows the two polygons: the union polygon and the purple polygon (the one whose effective blocking is being calculated)





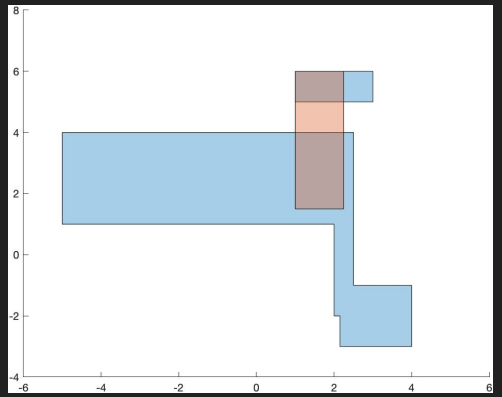
4. The purple polygon is now shown as the orange one and the polygons formed from the union of all the other polygons are in blue.

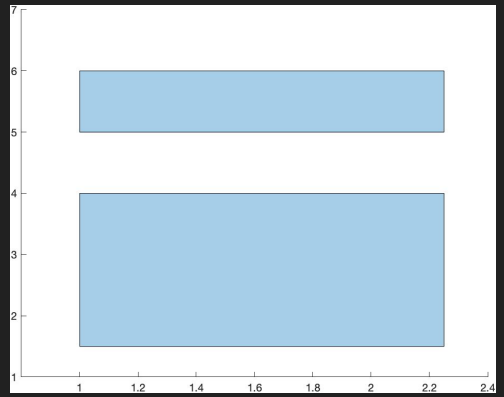
5. From the plot to the left we can see that the blocking area is given by the regions of overlap between the blue and the orange polygons.

6. It is evident that by making union polygons we are taking care of a region that is blocked by multiple polygons. This way we don't count the same region blocked by many polygons multiple times.

7. The next plot shows just the intersection regions.

8. The calculated blocked area is 4.375 units squared and the fractional blocking is 0.7778. The area is calculated using the polyshape object.



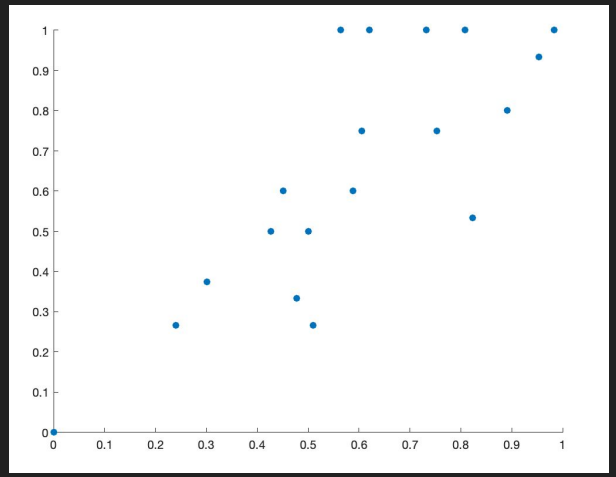


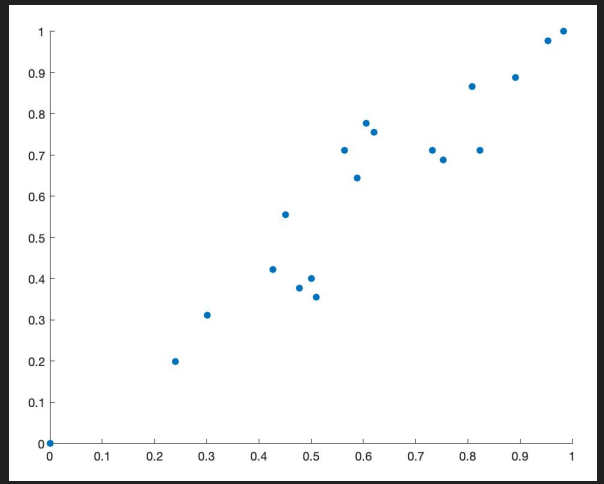
Model Testing

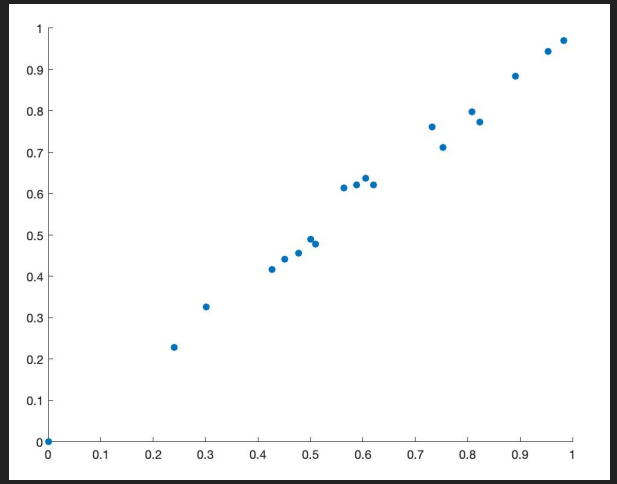
This model was put to test by comparing the results obtained from a function that calculated the area using a brute force method.

- The function using the brute force method plots points on the surface of each link and then stacks all the links on-top of each other in the specific positions that they are at a given instance.
- Then the function runs though the grid vertically.
- If a given point coincides with the link we are looking at and at least one other upstream link then that point is blocked.
- Then the function finds the ratio between such blocked points and the total number of points in a particular link and this is the fractional blocking.
- Increasing the number of points makes the results better
- We plot multiple graphs of the grid method vs the wind blocking method. And we see that as we increase the number of points on the grid our results get closer and closer to the results obtained from the wind blocking method.

These plots show the fractional blocking obtained from the grid method vs the wind blocking method for each link.
As we increase the number of points the results of the grid method gets closer and closer to the blocking method.
This gives us a 45 degree line.
Therefore, we can verify that the blocking method works.







Thank You!