Passive Oscillating Foils for Additional Propulsion under Calm Conditions

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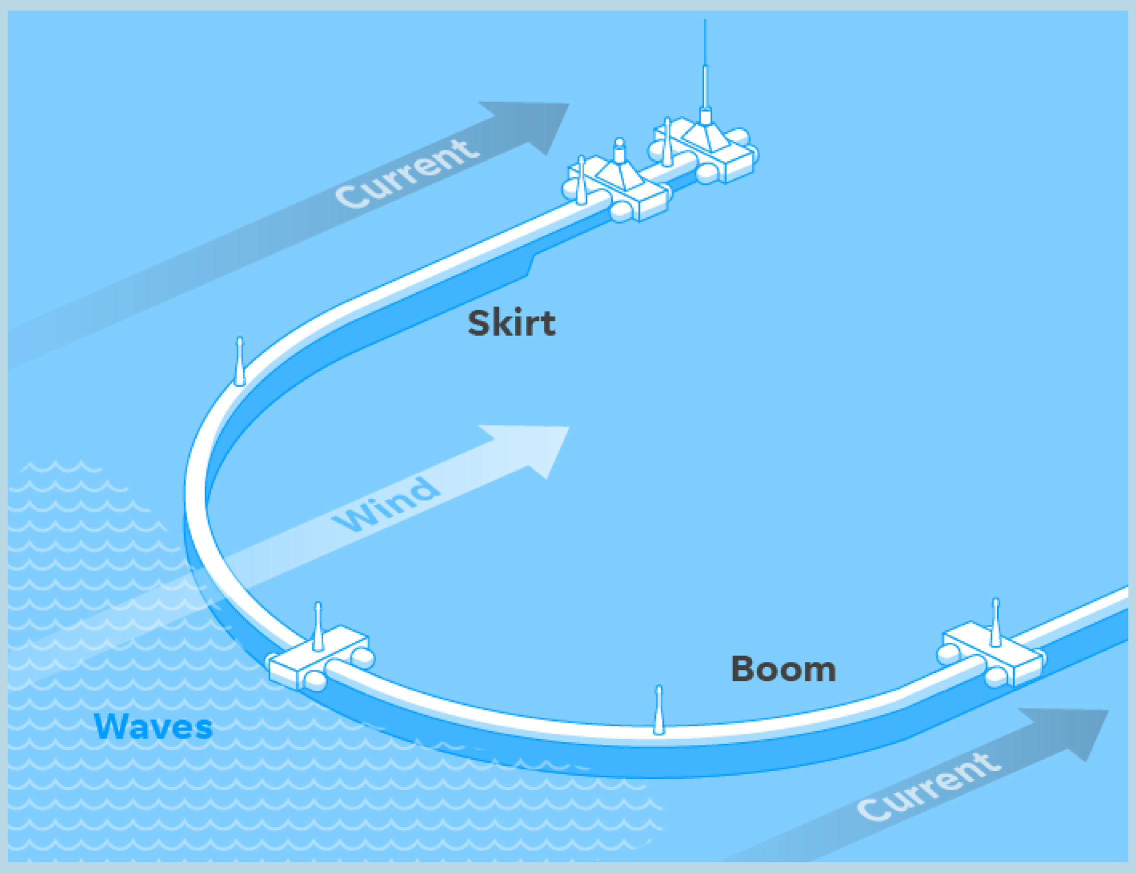
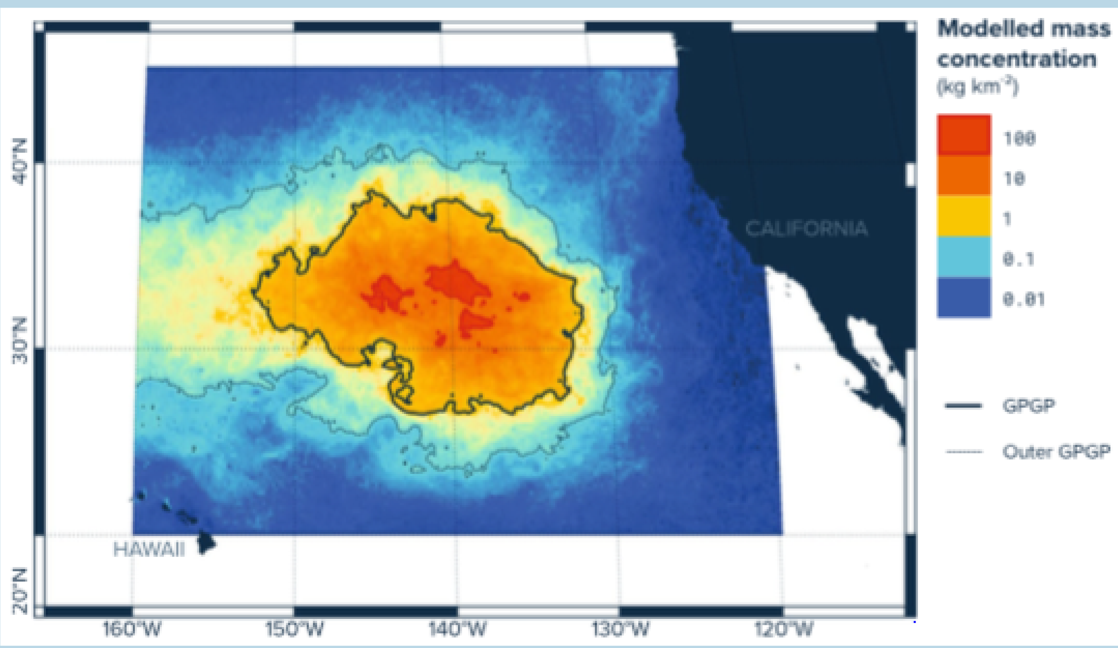
Introduction

Oceanic plastic pollution is a widespread problem with heavily documented environmental, ecological and economic impacts [1]. In order to limit the marine plastic problem, the plastic input altogether must be stopped. Nevertheless, by removing marine plastic that is already in the ocean, the harmful impact can be reduced.
In August 2018, The Ocean Cleanup launched its pilot cleanup project, System 001. The purpose of the system was to clean up the oceans of the world for plastic pollution, starting with the Great Pacific Garbage Patch (GPGP). System 001 consists of a 600 m long floater that sits on the water with a 3 m deep skirt attached below as illustrated in the figure below.



Although this system has shown that it is able to accumulate plastic, there have been issues related to the retention under calm conditions as the system drifts slower than the plastic. The figure below illustrates the plastic density in the GPGP.



Objective and Scope

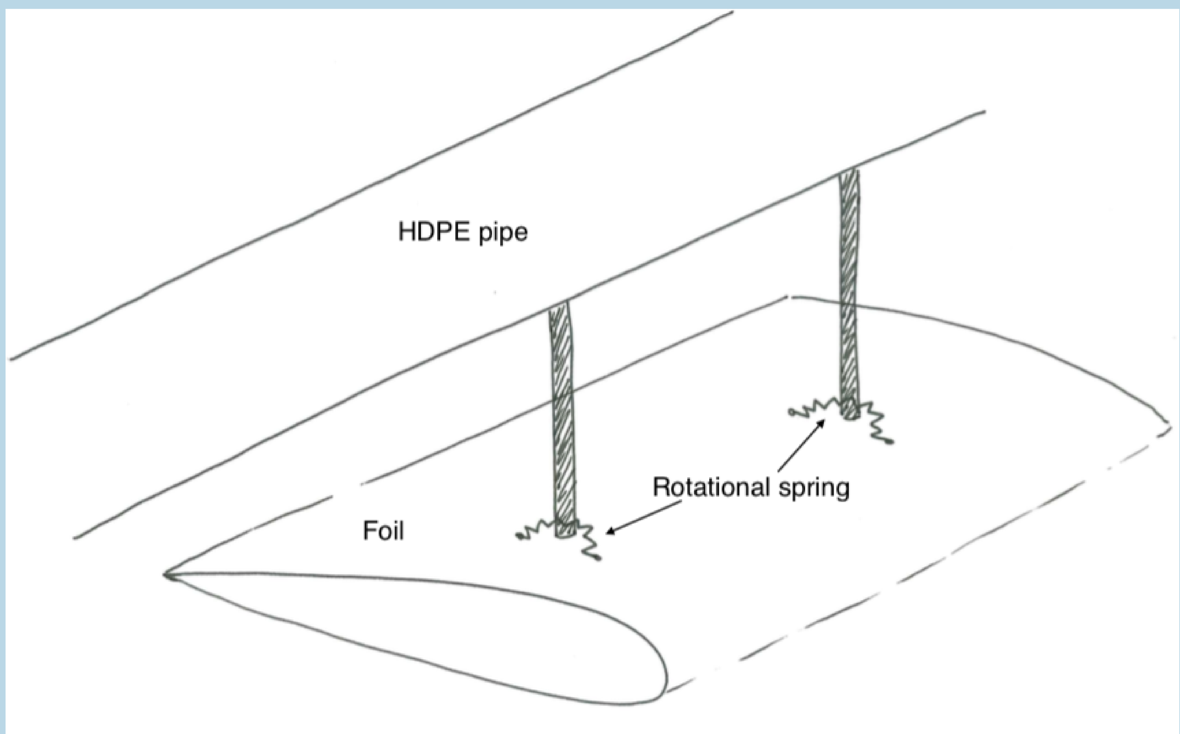
As the pilot project showed that System 001 was able to collect plastic, but could not retain the plastic under calmer conditions, the objective of this thesis is to look at possible solutions to this retention problem. Firstly, it will be relevant to conduct an analysis of the weather data in the GPGP. Further, different ways of utilising the natural forces acting in the area of interest will be investigated, before going into detail on one concept. Simulations will be conducted to assess if the concept of choice is a feasible solution to the retention problem.

References

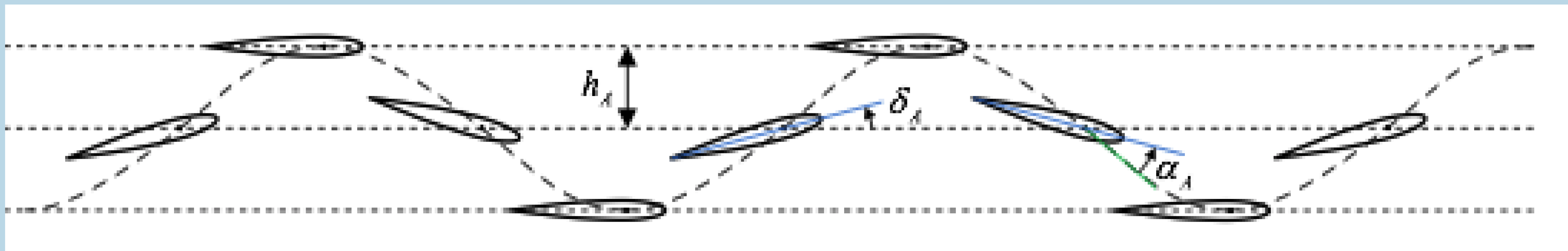
[1] Sherman, P., van Sebille, E. (2016). Modeling marine surface microplastic transport to assess optimal removal locations. Environmental Research Letters , 11 (1). Retrieved from http://search.proquest.com/docview/ 1776646104/

Concept description and model

Multiple concepts were discussed before concluding with one that would be investigated further. These included rudders under the system to utilise the currents, as well as kites and sails to make use of the wind in the area. Finally, it was decided to look deeper into the use of using passive oscillating foils for addition propulsion under calm conditions. This concept will make use of the waves in the area and is illustrated in the figure to the right.



The foil was placed at a depth of $\lambda/2 = 24\ m$ to avoid the particle movement from the waves. The heave motion was induced by the floater on the water surface and the pitching motion came as a result of the foil moving up and down with this motion. A rotational spring was attached at the pivot point to stop the foil from rotating too far. The figure below illustrates the heaving and pitching of a foil as it propagates in positive x-direction.



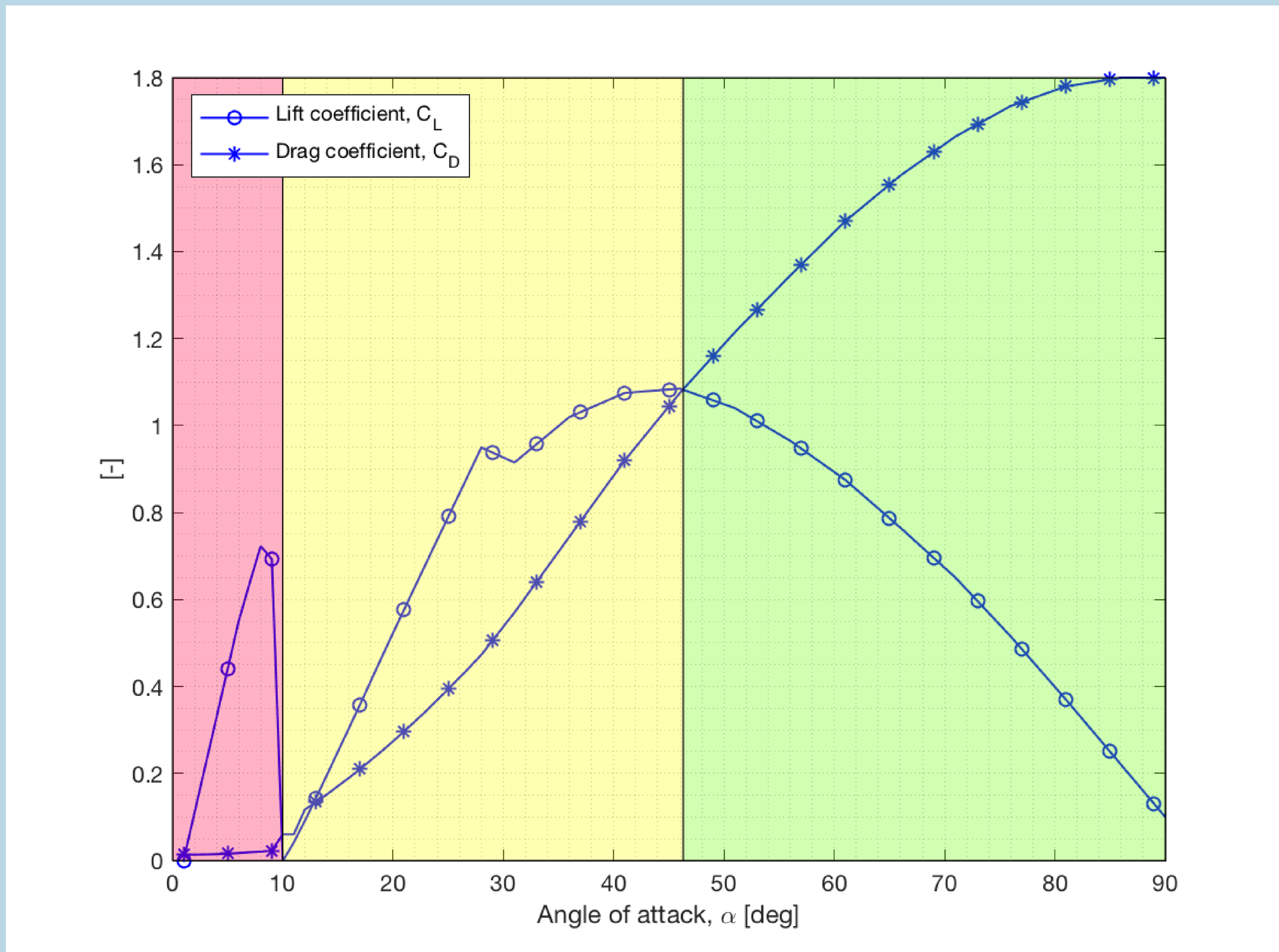
Further, an iteration process was conducted in order to find the optimal pivot point position, spring stiffness and pitch angle. When the pivot point position and spring stiffness are fixed, the following equation of moment equilibrium has to be fulfilled at every time instant by changing the pitching angle:

$$M_{hydro} = M_{spring} \tag{1}$$

where M_{hydro} is the moment induced by the lift, drag and added mass force acting on the foil, and M_{spring} is the momentum created by the spring stiffness and the pitching angle.

Results and conclusion

Using the minimum values obtained through a weather data analysis, iteration process could be conducted. The pivot point and the spring stiffness range were fixed and compared to find the optimal solution. With a pivot point at $x = 0.65\ m$ on a foil with chord length $c = 1\ m$ and span $b = 2\ m$. Using a spring of stiffness 1 Nm/deg, a total thrust of 116 N could be obtained by the use of passive oscillating foils.
The results also showed that the maximum thrust was obtained when the foil pitched between 45°and -45°, i.e. with angles of attack from 45°and 90°. This area is marked by the green area in the figure. The thrust was calculated by use of quasi-static and the following equation:



$$\overline{T}_{foil,qs} = \frac{\sum T_{ins}}{\text{Number of time steps}} \tag{2}$$

The drag of the floater and screen attached below will reduce the effective thrust of the system due to drag. This resulted in a total system speed of 0.1952 m/s. As the initial speed of the system was 0.0735 m/s, the results indicate an increase of 165% due to the use of passive oscillating foils.
The model used in this thesis is based on multiple assumptions. However, the model indicates that passive oscillating foils can possibly be used additional propulsion under calm conditions.

Acknowledgements

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