# Design of Artificial Seaweeds for Assessment of Hydrodynamic Properties of Seaweed Farms

Carina Norvik [carinan@stud.ntnu.no]
Supervisor: Dag Myrhaug, Co-supervisors: Pierre-Yves Henry and Andreas Myskja Lien

NTNU

SINTEF

## Introduction

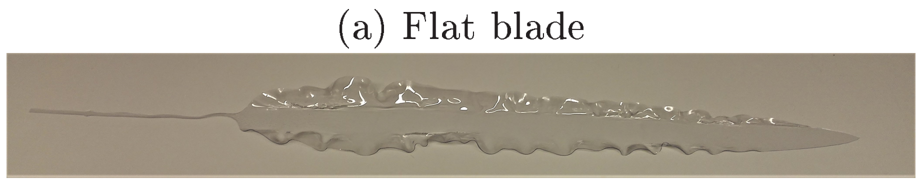
In recent years the prospect of having a seaweed based industry in Norway has become of interest. *Laminaria saccharina*, also known as sugar kelp, is one of the species of interest for the Norwegian seaweed industry [1]. Projects such as SINTEF Ocean's MacroSea are looking at the hydrodynamic properties of seaweed farms for assessment of the drag on the structure, as well as how the seaweed influences the flow characteristics. However, live organisms require care and small changes in parameters such as salinity can cause changes to its biomechanics and therefore changes to the fluid-vegetation interactions. Additionally, facilities such as towing tanks do not normally allow for biological material to be introduced. Surrogate models are therefore needed.

For a model to correctly replicate the real seaweed's interaction with the fluid, both blade and patch scale hydrodynamics should be reproduced, as the presence of neighbouring blades can change the flow structure [4]. One study compared the hydrodynamics of a single *L.saccharina* plant to flat blade models and found them to be good replicas [2]. However, it has been observed that a patch of flat blades flap with a lower amplitude and collapse together into a narrower bundle than a patch of undulate blades[3]. This causes self-shading and lower drag forces [4].

## Objective and Scope

This master thesis concerns the reproduction of the hydrodynamic properties of *L.saccharina* for design of surrogates for flow experiments. The objective is to look at two simplified models, see Figure 1, and compare their hydrodynamic properties by performing drag tests. Both blade and patch scale tests are conducted. Only unidirectional flow is considered.

(a) Flat blade



(b) Undulate blade

Figure 1: Simplified models of *L.saccharina*.

## References

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[2] D. Vettori. *Hydrodynamic Performance of Seaweed Farms: an Experimental Study at Seaweed Blade Scale*. Thesis, 2016.

[3] M. Koehl and R. Alberte. Flow, flapping, and photosynthesis of Nereocystis leutkeana: a functional comparison of undulate and flat blade morphologies. *International Journal on Life in Oceans and Coastal Waters*, 99(3):435–444, 1988.

[4] M. Luhar and H. M. Nepf. Flow-induced reconfiguration of buoyant and flexible aquatic vegetation. *Limnology and Oceanography*, 56(6):2003–2017, 2011.

## Methods

Towing experiments were conducted at the Marine Cybernetics laboratory at NTNU. Drag forces were measured at different speeds, while the movement of the models were recorded by a camera under water, see Figure 2.

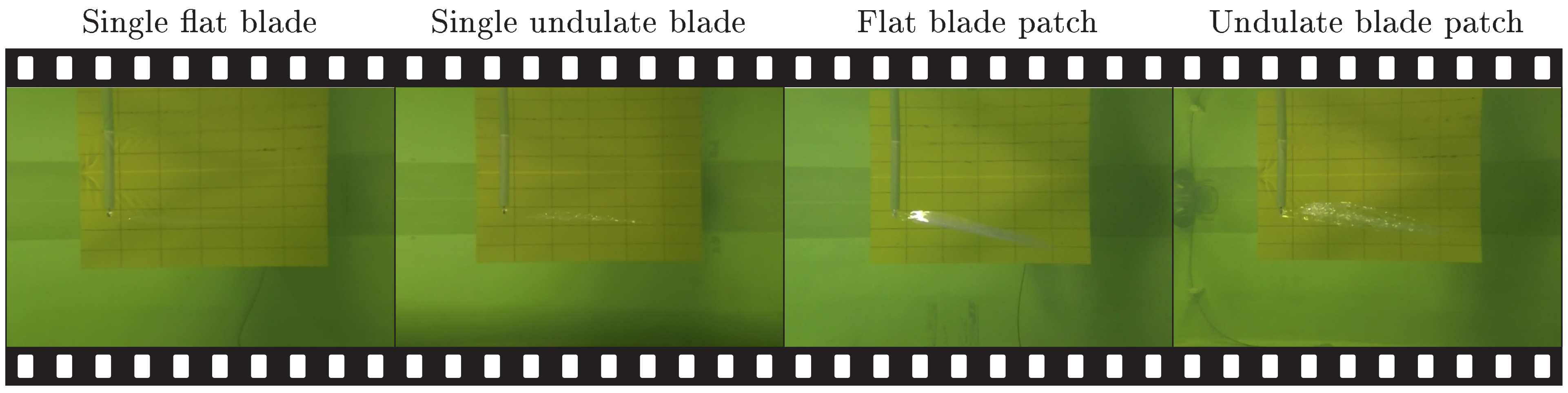


Figure 2: Stills from video recordings of the different models and arrangement under water.

The facility introduced noise and vibrations that had to be removed in post processing. The recorded data was filtered by using a low-pass filter. This allowed for high frequency disturbances to be removed without influencing the mean values and low frequency changes, see Figure 3.

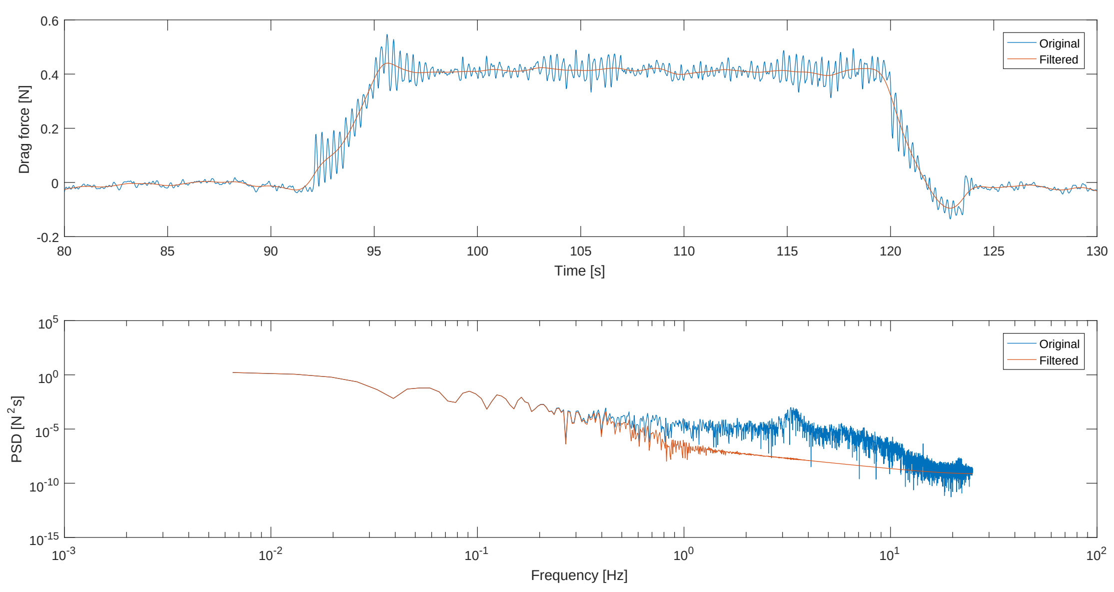


Figure 3: Example of measured and filtered runs and their power spectra.

## Results and Discussion

Figure 4 shows the development of drag force for patches of both models. At lower speeds, there was no significant difference between the drag experienced by the patch of flat and undulate blade models. However, as the speed increased the drag force experienced by the undulate models were greater. The same tendency was seen for the single blades. As was expected, due to self-shading, the drag experienced by a patch of models was not the drag experienced by a single model multiplied by the number of plants present.

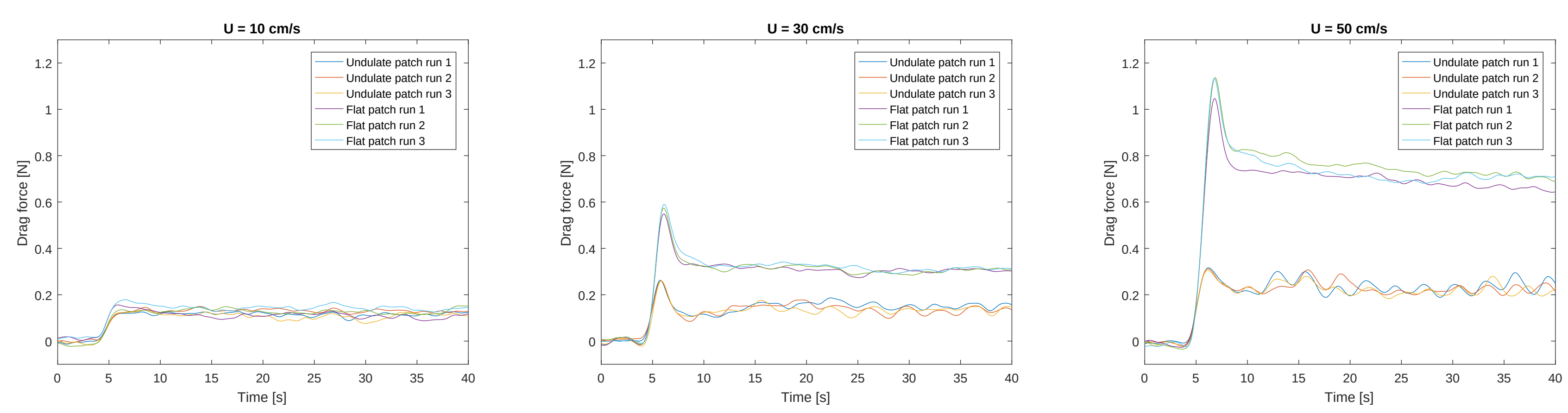


Figure 4: Drag force of flat and undulate blade patch at 10 cm/s, 30 cm/s and 50 cm/s.

From the videos, it could be seen that the patch of flat blades collapsed together while the undulate blades remained separated. However, this was not due to flapping, as no flapping motion was observed for the undulate blades. The lack of oscillation in the drag forces for undulate blade patch supports this observation, and is in contrast to previous studies. The larger drag for the undulate patch of models is likely due to the lack of self-shading, as the blades remained separated even without flapping. Both the lack of self-shading and the lack of flapping motion could be due to the flexural rigidity, i.e. stiffness, of the models being approximately 4 times that of the natural seaweed.

## Conclusion

Unlike previous studies, the flat blade patch had visible flapping motion while the undulate did not. Even so, the drag force for the undulate model and patch was larger. The larger drag, even with lack of flapping, could be due to the stiffness of the models being too high.

## Acknowledgement

A special thanks goes to the staff working at the laboratories at Tyholt; Torgeir Wahl, Trond Innset, Ole Erik Vinje and Marcus Almehagen. Without their help and guidance the drag experiments could not have been performed.