SINTEF REPORT

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TITLE

Load Measured on Net Panels in the Flume Tank

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ABSTRACT

This study is performed to help understand the drag and lift forces on net panels. Net panels are an important part of trawls and net cages. We hope to help computer simulations to use improved information on the forces acting on netting in water.

This study have measured the forces on various types of netting and provide drag and lift coefficients. The netting have been subjected to multiple velocities of water flows, and the measurements were performed at various angles between the water flow and the net, also known as the yaw angle.

We have after careful measurements of Cdrag and Clift on three net panels at various angels shown that Cdrag can be represented by a function depending on the diameter of the thread, the velocity of the net compared to the water, and the angle of the net panel to the water flow.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1		
GROUP 2		
SELECTED BY AUTHOR		

TABLE OF CONTENTS

1 Introduction

This study is performed to help understand the drag and lift forces on net panels. Net panels are an important part of trawls and net cages. We hope to help computer simulations to use improved information on the forces acting on netting in water.
This study will measure the forces on various types of netting and provide drag and lift coefficients. The netting will be subjected to multiple velocities of water flows, the measurements are performed at various angles between the water flow and the net, also known as the yaw angle. First, the setup and procedures used in the flume tank will be presented. This is followed by a presentation of the results measured. Finally, we show how the measurements can be converged into a model for drag coefficient for a net panel.

2 Setup

2.1 Flume tank

The flume tank facility used is located in Hirtshals, Denmark and operated by SINTEF [1]. The measuring section of the flume tank has the dimensions 21.3 m by 2.7m by 8m. The maximum water speed is 1 m/s. An artificial bottom has for the purpose of these measurements been locked to the water speed.

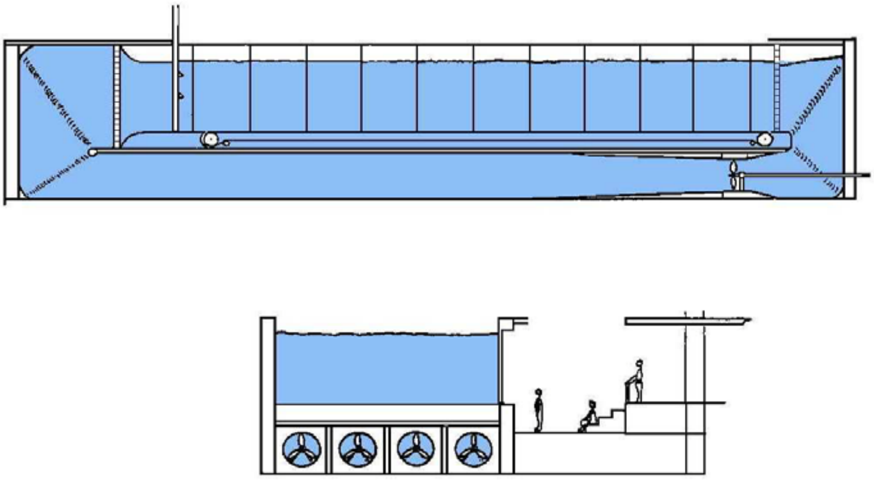


Figure 1 Schematic showing of the flume tank from side and front.

2.1.1 Net panels

The net panels under investigation is a white fish trawl net, a scrimp trawl net, and model net. See the table below for characteristics of the net panels

Table 1 *Characteristics of the Net panels*

Net panel	*Twine diameter [mm]*	*Mesh length [mm]*	*Area 20% opening [m2]*	*Area 30% opening [m2]*	*Area 40% opening [m2]*	*Scale*	*Re at 0.32 m/s*
1 (white fish)	4.6	160	0.600	0.467	0.295	1:1	1276.3
2 (scrimp)	1.4	50	0.605	-	0.295	1:3	446.7
3 (model)	0.5	18	0.610	-	0.327	1:10	153.2

The Reynold number,Re is calcultated based on the assumption, that the net can be seen as a set of cylenders.

$$R_e = vL\frac{\rho}{\mu}$$

Where L is the diameter of the twine in the netting, v is the velocity, ρ the density, and μ is the dynamic viscosity of the fluid.

The net is sown on to a guiding rope to fixate the level of opening (see Fig. 5).

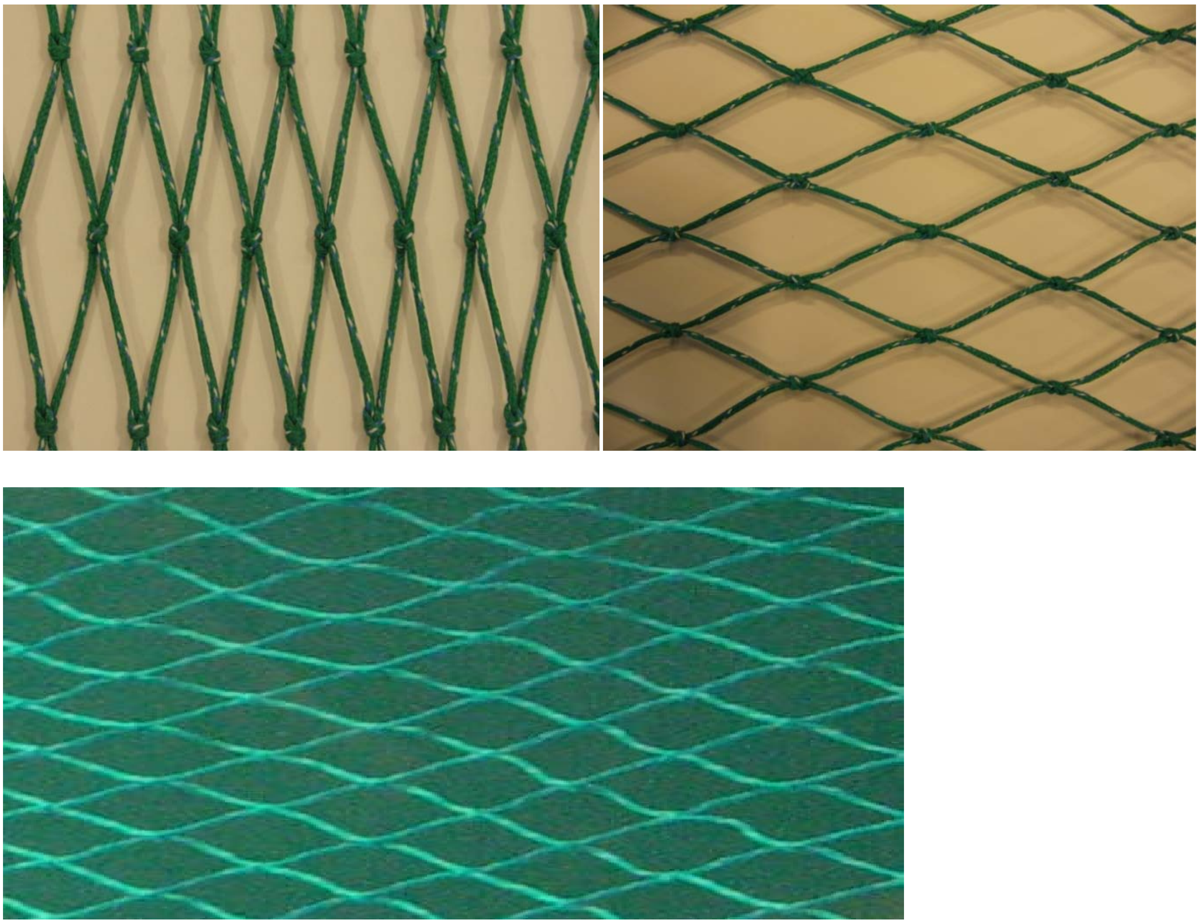


Figure 2 Net 1 White Fish Trawl Net 1:1. Top Left has 20% opening, Top Right 40% opening, and bottom 30% opening. Note: for the 30% opened net the picture is taken at 60 degree yaw.

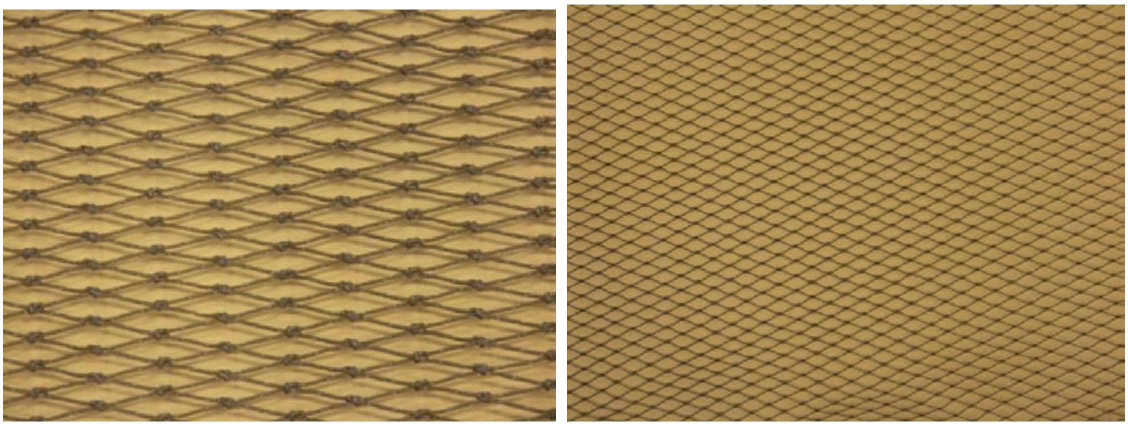


Figure 3 Net 2 Scrimp Trawl net 1:3. Left net with 20% opening, right net with 40% opening.

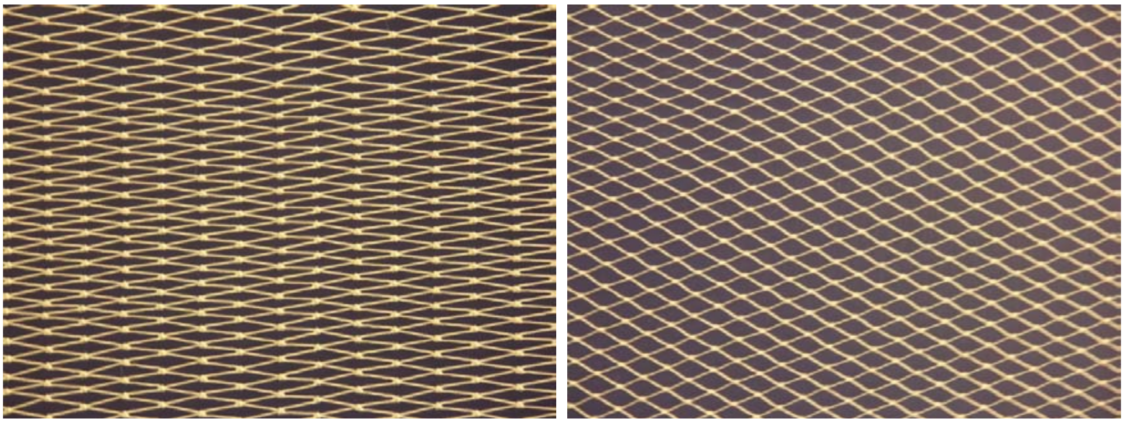


Figure 4 Net 3 Model net 1:10. Left net with 20% opening, right net with 40% opening.

2.2 Frame

A metal frame of circa 2.2m by 1m is used to fixate the net. The netting is sown on to the metal frame. The frames with the net panels are equipped with reflective markers on the top of the frame. This allows the motion tracking system to determine the exact position and angle of the frame in the flume tank. Below is shown the frame including a guiding robe which was used for measuring the forces on the frame itself. The metal frame provides a possibility to securely attach to the load cell.

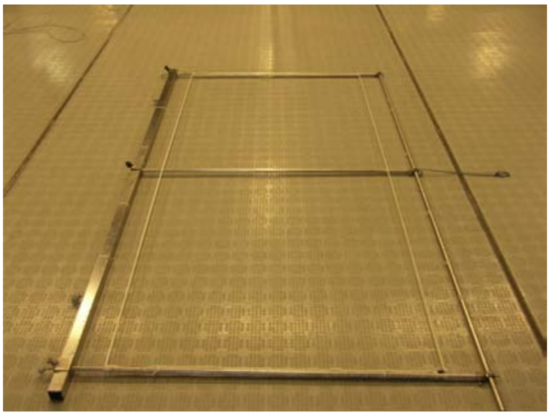


Figure 5 The frame with guiding rope

2.3 Load Cell

The ATI Multi-Axis Force/Torque Sensor system measures six components of force and torque. The load cell is described in the website below.

Source: http://www.ati-ia.com

The Force/Torque (F/T) sensor system measures the full six components of force and torque (Fx, Fy, Fz, Tx, Ty, Tz) using a monolithic instrumented transducer. The F/T transducer uses silicon strain gages for excellent noise immunity. The use of silicon gages allows the F/T transducer to have high stiffness and increased overload protection. All transducer models are available with Net F/T, DAQ F/T or Controller F/T interfaces. The load cell is equipped with a DAQ interface; the data is logged using a simple program which was delivered with the load cell. The capacities of the load cell used for the test on the netting panels are shown in the second column in the table below.

Tabell 1 Characteristics of the Load Cell

Description	**Omega 160**
Max Fxy [±N]	±2500 N
Max Txy [±Nm]	±3600 Nm
Max Fz [±N]	±6250 N
Weight	7.26 kg
Diameter	170 mm
Height	55.9 mm

2.4 Tether

To prevent overloading of the load cell and to prevent the shape of the test object from being distorted by the forces due to the water flow, we added a tether to the bottom of the frame. The tension in this tether is measured using an inline load cell. This tether is attached parallel to the global y axis in the centre of the net frame. This makes it easy to add this force measurement to the load cells force measurement after transformation to the global coordinate system.

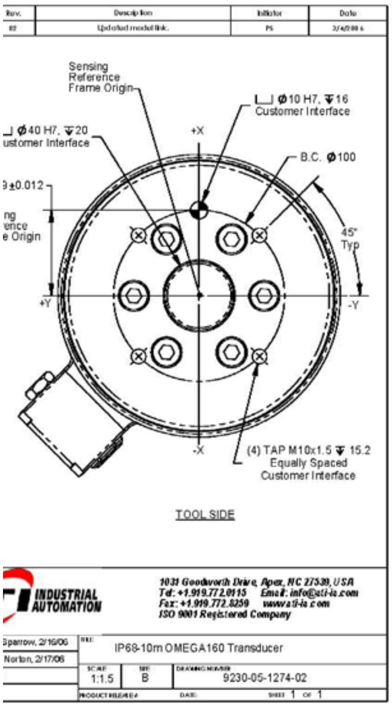
2.5 The Suspension Tower

The tower is used to secure the net frame. The tower can position the frame in the water by lifting and lowering the attachment piece. The object can also be rotated around the Z axis by about 160 degrees (the attack angle of the water flow). The pitch and roll angle of the object can also be manipulated by +/- 20 degrees.

The tower is bolted to the observation bridge over the flume tank.

2.6 Connecting Pieces

The face of the load cell pointing towards the test object has a number of threaded holes machined for attachment of a test specimen as shown in the drawing below:



In this case the circular disc attached to the load cell is connected to the net suspending frame by a 300 mm long rod to minimize the influence of the test tower on the flow against the netting panel.

2.7 Motion Tracking/Qualisys and the Reflective Markers

We use motion tracking hardware and software from Qualisys. More information about the company which has specialized in motion tracking can be seen in the company website

http://www.qualisys.com/

Our system consists of six cameras which can be submerged in the water enabling us to cover the motion of objects in a volume of the flume tank with like shown in the figure below. Each square in the grid shown in the figure has a size of 1x1 m. In the figure the actual positions of the six cameras can also be seen. We have mounted four cameras on a beam in the aft end of the tank and two extra cameras further forward on a second beam to get a good coverage of the tank volume.

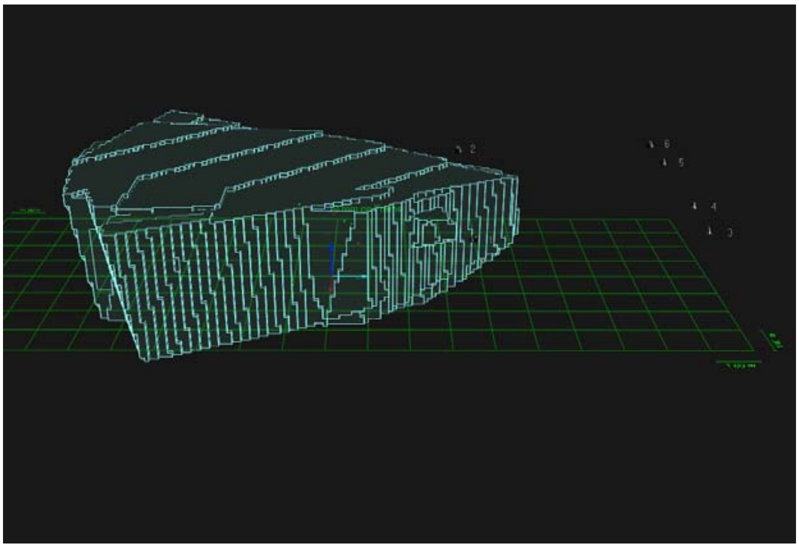


Figure 6 Illustration of the volume being monitored by the motion tracking system.

The frames with the net panels are equipped with reflective marker on the top of the frame. This is to enable the motion tracking system to determine the position of the frame in the water. This information is used to link the coordinate system of the load cell to the global coordinate system. The calibration of the motion tracking system is done once a day, and has an accuracy of ~4 mm.

3 Procedure

The frame with the suspended net panel is submerged in water and placed at the yaw angle under investigation. The load cell is biased and an initial measurement with out water flow is conducted. This measurement is used to subtract the bias from the subsequent measurements at this yaw angle. Following this, the water flow is increased to the lowest velocity under investigation and the load cell and the motion tracking system measures for 100 seconds. The measurement series are done in such an order that the water flow is increased while the yaw angle is kept constant. This is to minimize the need for biasing the load cell to many times. After all measurements at a given yaw angle the water flow is stopped. When the water flow reaches zero m/s the frame with the net is placed in the angle for the next measurement series. The water speeds used is 0.32m/s, 0.64 m/s, and 0.90 m/s.

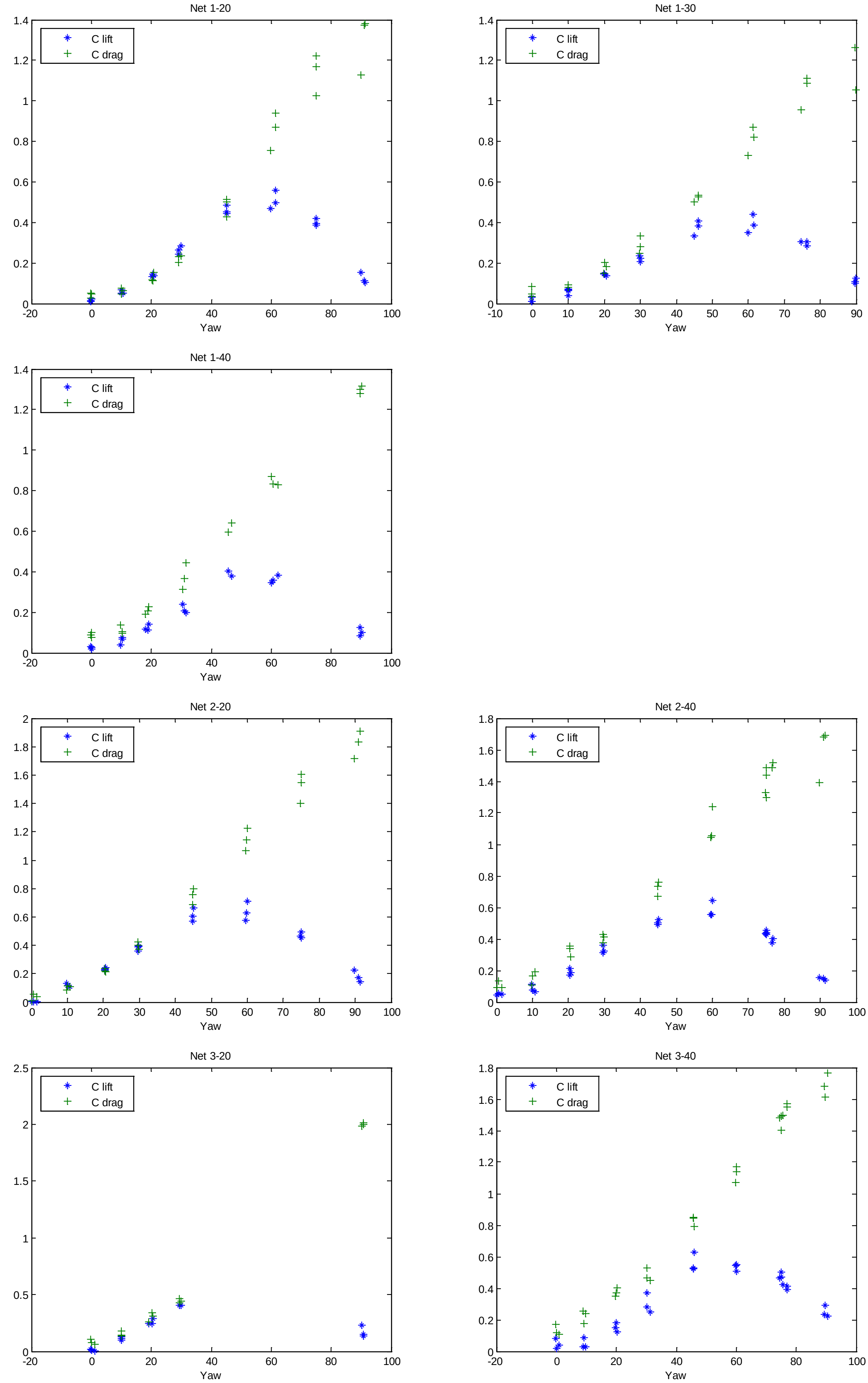
When measurements for all angles and all speeds of water flow has been performed the frame with the net panel is extracted from the water, and the frame is separated from the load cell. Pictures are taken of the net while it is still on the frame. The height and length of the net is measured and the number of masks is counted. This information is used to calculate the area of the net panel.

4 Results

The measured forces are used to calculate the lift and drag coefficients:

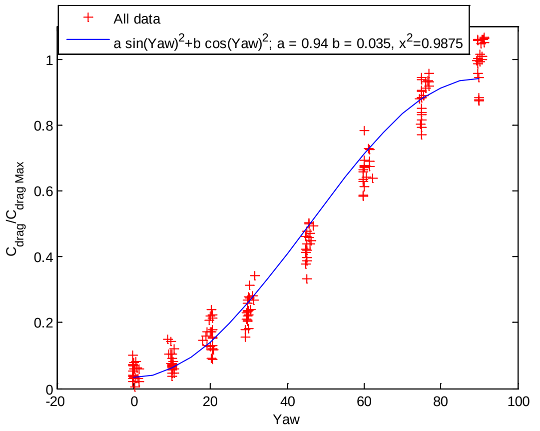
$$C_{drag} = \frac{F_x}{\frac{1}{2}v^2 A\rho} \qquad C_{lift} = \frac{F_y}{\frac{1}{2}v^2 A\rho}$$

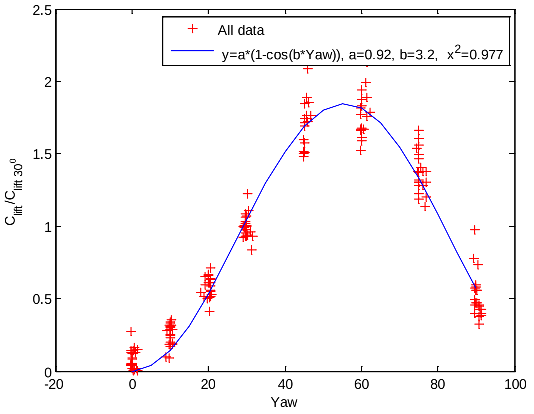
The drag and lift coefficients are plotted against the measured yaw angle in the following plots.



The figures above show the curves of drag and lift coefficients measured on the various net panels. In general we see similar shapes of for the various nets and openings. The maximum occur at the same yaw angles, but the values differ.

To investigate this further we have normalised the drag and lift coefficients to the maximum and 30 degree yaw respectively.





The C drag can be fitted with Cdrag(Yaw) = Cdrag_max (0.94 sin^2(Yaw)+0.035 cos^2(yaw)) where the sine part is attributed to the pressure force, and the cosine part to the friction force.

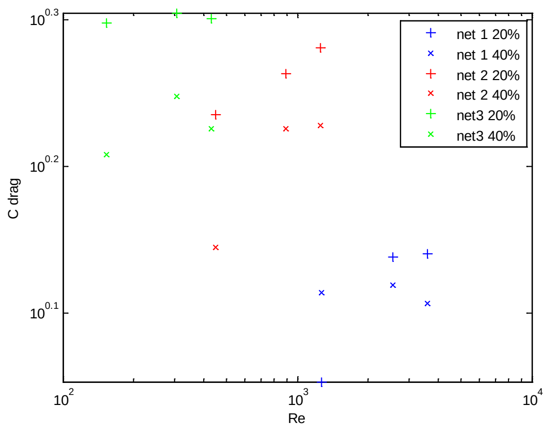
$$C_{drag}(\text{Yaw}) = \mathrm{C}_{\mathrm{drag}_{\max}}\,[0.94\sin^2(\text{Yaw}) + 0.035\cos^2(\text{Yaw})]$$
$$C_{lift}(\text{Yaw}) = C_{\text{lift (Yaw=30)}}[0.92(1-\cos(3.2\text{Yaw}))]$$

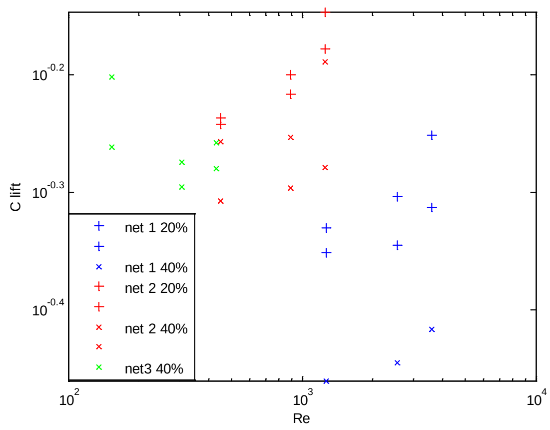
According the fit of Clift; the maxima occurs at a yaw angle of 56.25 degrees. Hence the Clift max is 1.84 * Clift(30 deg).

Table 2 Measured maximum drag and lift coefficient

Net Panel	*C drag max*	*C lift max*
Net 1-20	1.30	0.48
Net 1-30	1.19	0.41
Net 1-40	1.30	0.40
Net 2-20	1.82	0.70
Net 2-40	1.59	0.61
Net 3-20	2.00	0.75
Net 3-40	1.69	0.55

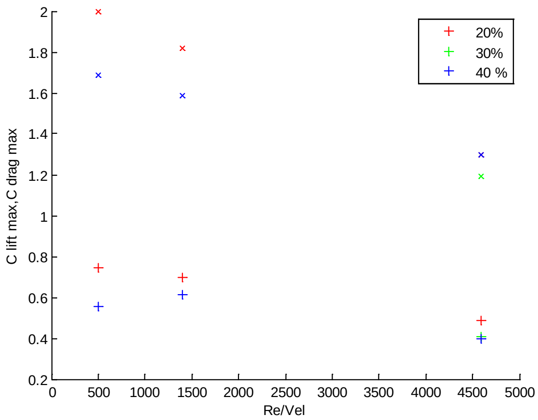
Ploting the C drag and C lift versus the Reynolds number (see below) show an unclear picture of relationship.





Based on literature [2] we would expect an increase in the drag coefficient the smaller the Re. We don't see a clear picture of this. However, just looking at the cloud of measured points we do get the expected general shape. Each point in the plot corresponds to only one measurement, so the measurement error might be significant.

Below the Cdrag and Clift(lovest set of numbers) are plotted against the Reynold number over the velocity. Each point on the graph is an average over the velocities.



Liniar fits on the above data gives for 20% net opening and 40% net opening respectively:

20% Opening

$$C_{drag}(Y, R_e, v) = \left(-2.01 * 10^{-4}\frac{R_e}{v} + 2.10\right)[0.94\sin^2(Y) + 0.035\cos^2(Y)]$$

$$C_{lift}(Y, R_e, v) = \left(-6.68 * 10^{-5}\frac{R_e}{v} + 0.79\right)[0.92(1 - \cos(3.2Y))]$$

40% Opening

$$C_{drag}(Y, R_e, v) = \left(-1.11 * 10^{-4}\frac{R_e}{v} + 1.74\right)[0.94\sin^2(Y) + 0.035\cos^2(Y)]$$

$$C_{lift}(Y, R_e, v) = \left(-4.57 * 10^{-5}\frac{R_e}{v} + 0.62\right)[0.92(1 - \cos(3.2Y))]$$

The drag and lift coefficient as shown above for the net panels shows a linear dependency of the Reynolds number(*Re*) over the velocity(*v*), and a dependency of the yaw angle(*Y*).

5 Discussion

The results shows that net panels drag and lift coefficients can be described by the same basic mathematical function, independently of their thread and mesh opening. The Reynolds number of the thread in the net panel divided by the water flow velocities, affects the maximum drag and lift coefficient.

However, the measurements show a clearer trend for the shape of the Cdrag and Clift plots versus attack angel (Yaw), than the Re/velocity dependency; it could therefore still be valid to measure maximum Cdrag and Clift for specific net panels that is of special interest.

6 Errors and Uncertainties

*The connection piece used between the frame with the net and the load cell can not be aligned 100% to the load cell

*The frame might settle when the water flow is increase

*Qualisys calibrations are only as good as the L-shape being placed at the bottom. Normally the L-shape used for the calibration is replaceable on the carpet within 5mm of the previous calibration

*The calculation of the area of the net panels has been done by a calculation based on the diameter of the thread in the net

7 Conclusion

After careful measurements of Cdrag and Clift on three net panels at various angels we have shown that the coefficients can be calculated based on the diameter of the thread, the velocity of the net compared to the water, and the angle of the net panel to the water flow.

8 References

[1] SINTEF Fisheries and aquaculture flume tank
http://www.sintef.no/Home/Marine/Fisheries-and-Aquaculture/Laboratories-and-software/Fishing-Gear-Laboratory/

[2] "*Fluid-Dynamic Drag*" by Hoerner, 1965