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On the Way to Plankton Net Calibration

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Outline

- Introduction
- Methods
- Results
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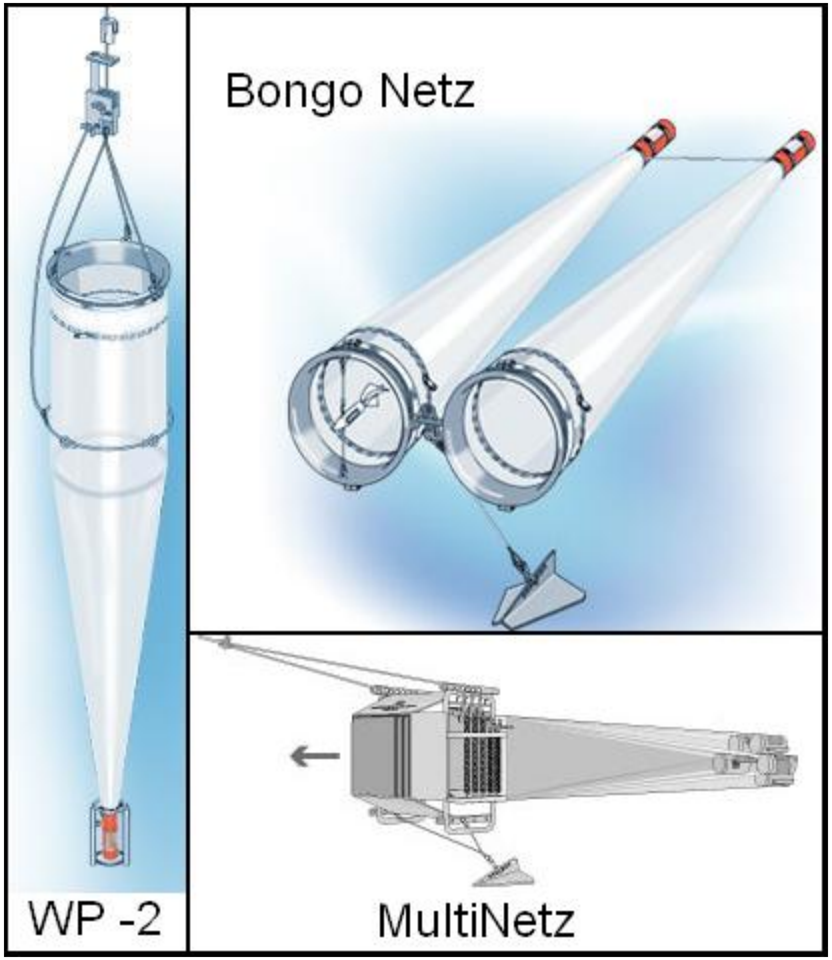
- Future Work

Introduction

- Zooplankton is an important link in the marine food chain. It connects lower trophic levels like algea with higher trophic levels like fish.
- To identify global synchronies in zooplankton populations a need for intercalibration to document gear and sampling differences arose.

→ Investigate hydrodynamic properties in an appropriate testing facility, or

→ use computational fluid dynamics (CFD) methods.



Introduction

Investigate the hydrodynamics of plankton nets with CFD methods.

- Predict the flow patterns around and through plankton nets with Reynolds averaged Navier-Stokes (RANS) methods.
- Asses the method by comparing CFD results with experimental flow investigations done by Tranter & Heron (1968) and Enerhaug (2005).

Methods

- RANS methods provide time-averaged information about flow properties

⇒ A constant towing velocity was ensured during measurements in the testing facilities and,
⇒ clogging effects were not considered.

Methods - Problems to face

Weights are used, e. g. WP-2 net:

25 kg lead weight at the end.

↳ Assumption: nets are rigid.

- Nets are flexible structures
- Mesh opening is too small to model each mesh (max. mesh opening approx. 0.5 mm)

↳ Physical properties of the gauze are simulated by defining a directional pressure loss over a porous body representing the gauze.

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Methods - Flows in porous media

$$\frac{\partial \overline{u_i}}{\partial t} + \frac{\partial \overline{u_i}\,\overline{u_j}}{\partial x_j} = \overline{f_i} - \frac{1}{\rho}\frac{\partial \overline{p}}{\partial x_i} + \nu \cdot \frac{\partial^2 \overline{u_i}}{\partial x_j^2} - \frac{\partial \left(\overline{u_i' u_j'}\right)}{\partial x_j} + S_i,$$

$$S_i = -C_{R1i} \cdot u_i - C_{R2i} \cdot |u_i| \cdot u_i$$

C_{R1i} – linear resistance coefficient

C_{R2i} – quadratic resistance coefficient

u_i – superficial velocity

Ansys CFX directional loss model requires C_{R1} and C_{R2} in the streamwise direction

Methods - Directional pressure loss

- Magnitude of the pressure loss (C_{R1}, C_{R2})?
- Direction of flow out of the gauze?

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Methods - Directional pressure loss

Pressure loss over gauze screens perpendicular to the flow

- Experimental data
- E. Brundrett, 1993 - formula to calculate the pressure loss over gauze screens

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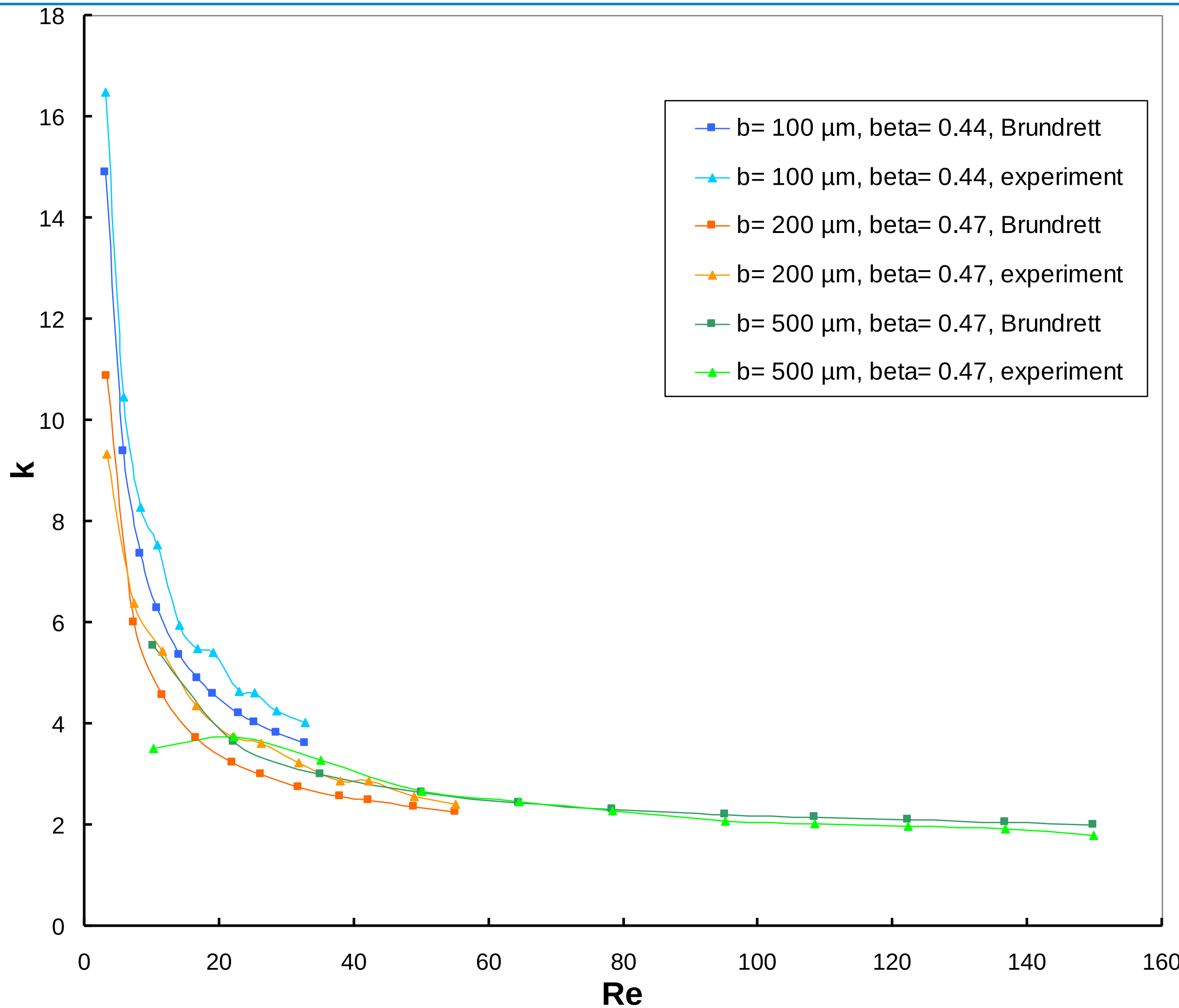


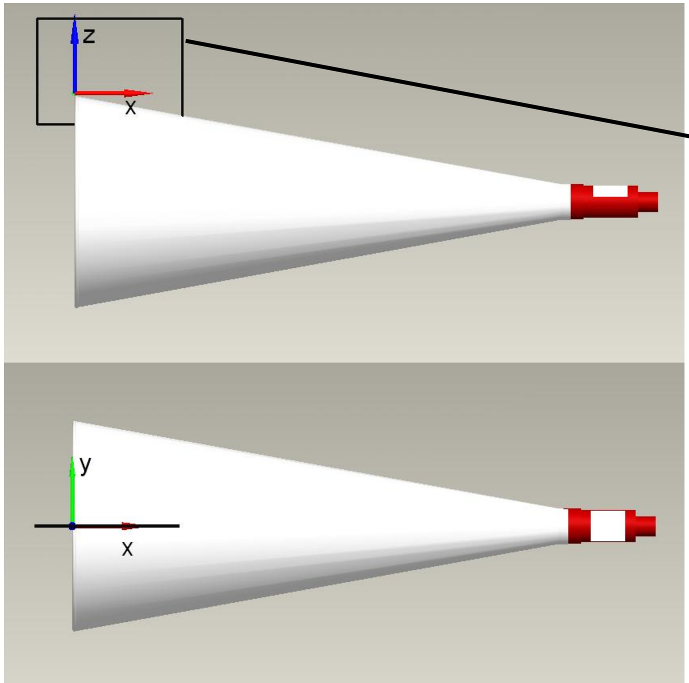
$$k = \frac{\overline{\Delta p}}{\frac{1}{2}\rho \cdot u_0^2}$$

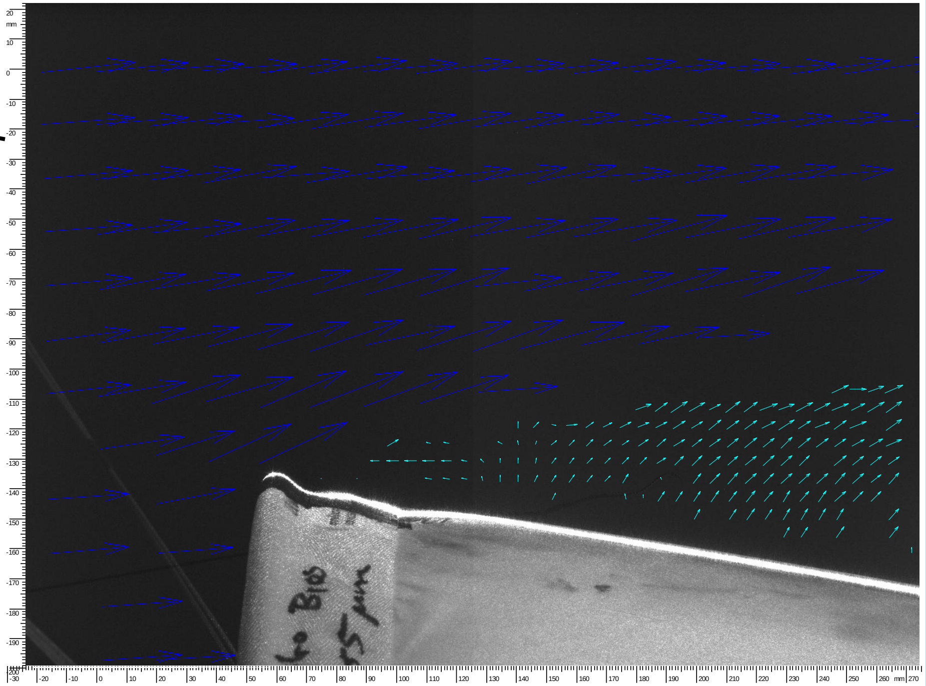
$$\mathrm{Re} = \frac{u_0 \cdot d}{\nu}$$

Methods - Directional pressure loss

A. J. Reynolds, 1969 – porosity less than 0.5 ⇨ direction of outflow normal to the gauze screen

Results of Particle Image Velocimetry (PIV) System - measurements





Methods - Directional pressure loss

Assumptions

- Nets are rigid
- Pressure loss is predicted by the formula given by Brundrett
- Direction of flow out of gauze normal to the gauze

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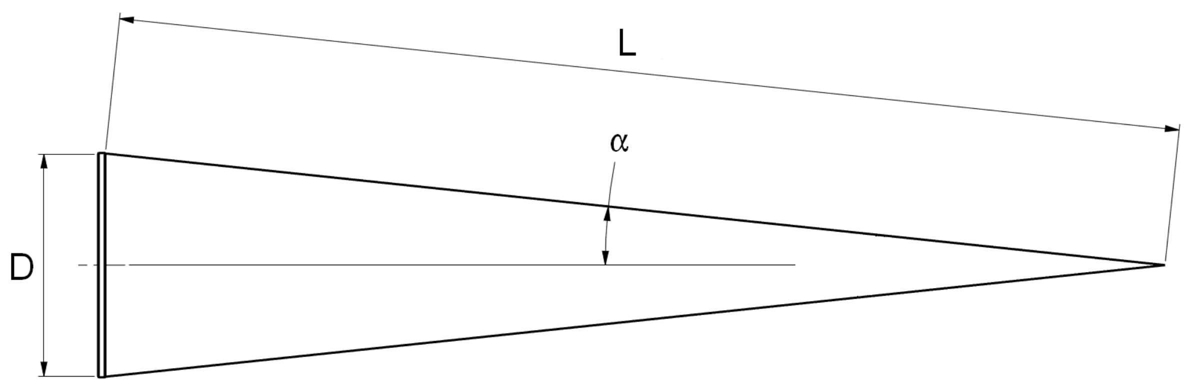
Methods - Test objects

net	abbreviation	mouth diameter (D) in m	length of side (L) in m	taper angle (α) in deg.	mesh opening (b) in µm	Twine diameter (d) in µm	Porosity (β)
prototype WP-2 net	N22	0.67	2.42	6.3	210	90	0.49
Enerhaug model 1.4	E14	0.8	1.56	15	500	230	0.47
Enerhaug model 3.1	E31	0.8	3.85	6	950	305	0.57
Enerhaug model 3.2	E32	0.8	3.85	6	143	153	0.23



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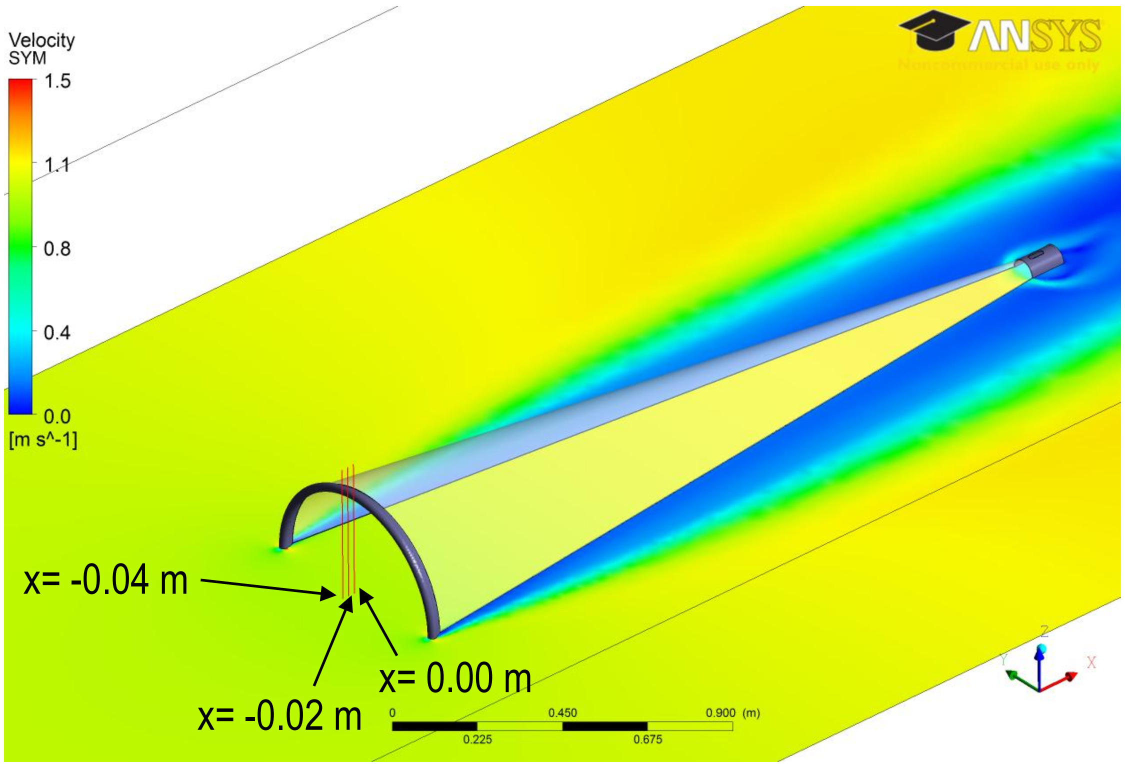
Results

Results

Simulation of prototyp WP-2 Net, Tranter & Heron „Zooplankton sampling“, UNESCO report 1968.



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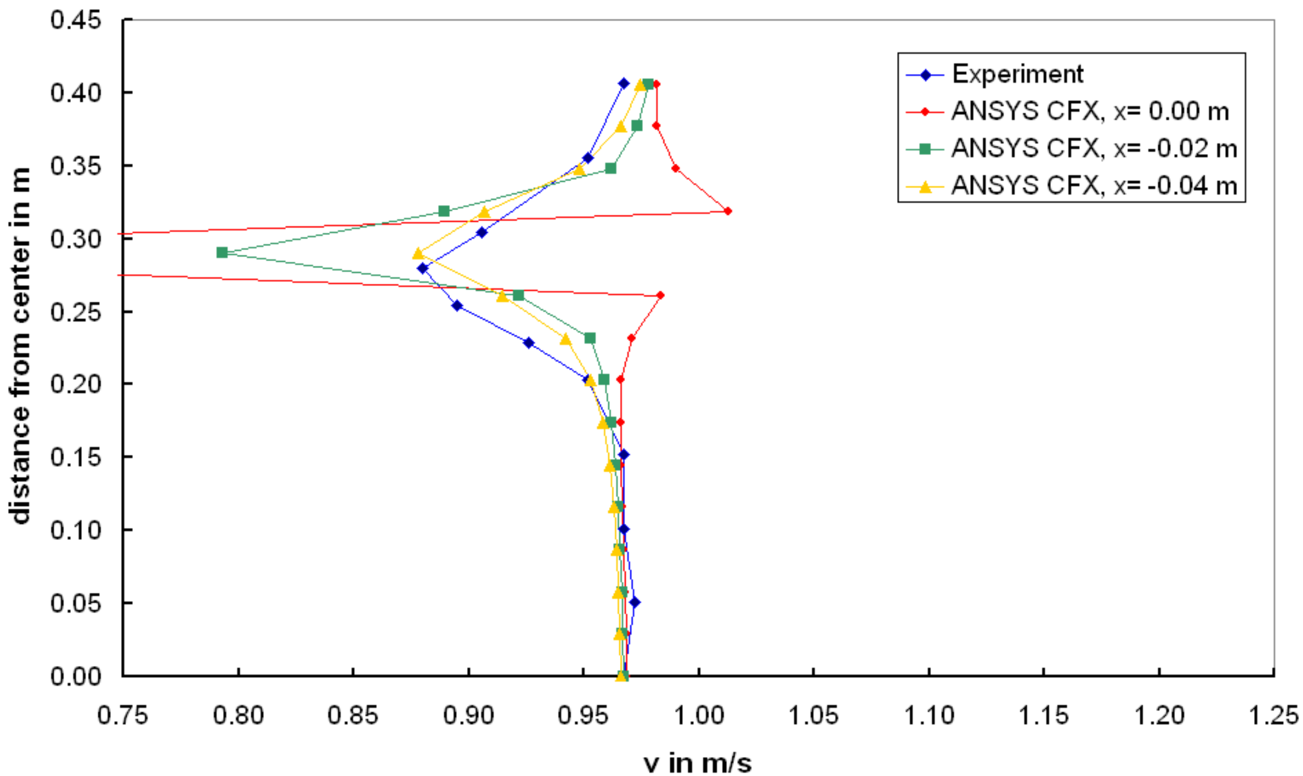
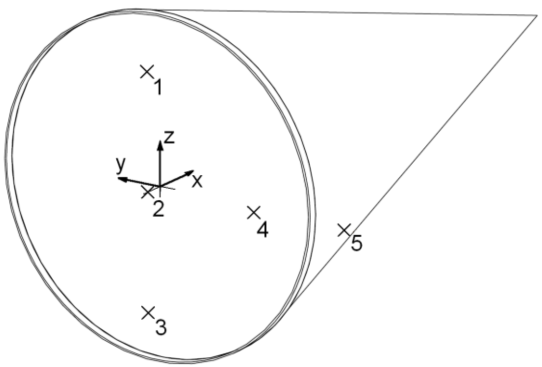
Results

The prototype WP-2 net



Results

Enerhaug nets: E14, E31, E32



Volume flow rate *Q* into the net, based on Enerhaug

$$Q_{net} = \frac{(u_1 + u_3 + u_4)}{3} \cdot A_{mouth}$$

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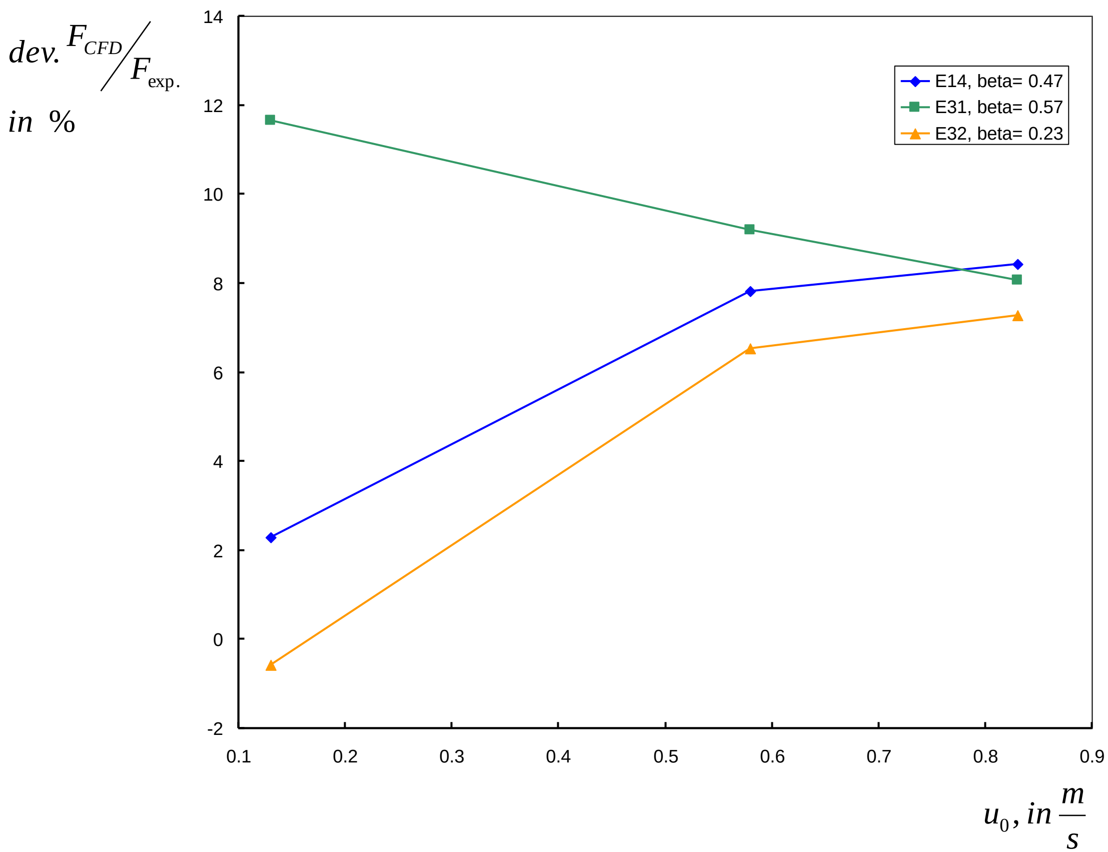
Results

Enerhaug nets: E14, E31, E32



$$F = \frac{Q_{net}}{Q_{theory}} = \frac{Q_{net}}{u_0 \cdot A_{mouth}}$$

F – filtration efficiency

Q – volume flow rate

u_0 – approach velocity

A_{mouth} – mouth area net

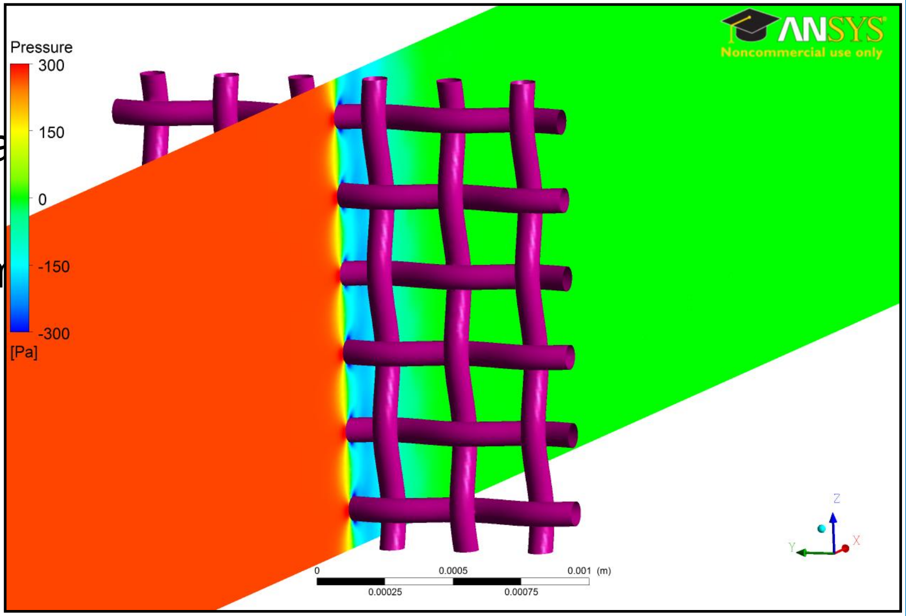
β – porosity of gauze

Conclusion

- Promising results about the application of RANS methods to predict the hydrodynamics of plankton nets have been obtained.
- Deviations up to 13% occurred, on average 7 %.
- Weak point of the simulation is its simplification of the gauze assumed as a porous body.

Future work

- Investigate the flow through inclined ga
experiments and simulations
- Find a way to describe the hydrodynam
- Compare any kind of plankton net with
net



Thank you for your attention!