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Towed Gear Optimisation, application to trawls

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1 A tool for optimising trawls

IFREMER has been developing and commercialising scientific software to help the conception and optimisation of any kind of trawl. This software named DynamiT makes available a “virtual flume tank” where tests can be achieved without any constraint due to scale effects or other limitation when physically testing out. DynamiT has been used numbers of times to simulate and optimise trawls by different net makers and by IFREMER. The software is based on the resolution of the mechanics (structure and hydrodynamic) equations of a model describing the actual trawl and its rigging. The “user friendly” interface allows the user to iterate “modification and observations” cycles to reach an optimised state of the fishing gear. The process can be used to reduce the hydrodynamic drag of the trawl, consequently to reduce the fuel consumption.

It is generally admitted that the fuel consumption can be shared as follows :

- 1/3 is used for the trawler (propelling the hull when steaming or during the fishing operations, hydraulics, cold …)
- 2/3 is used to tow the trawl.

These figures are average values and are very dependent of the exploitation conditions.

Consequently, in the following figures (chapter “Applications”), one has to multiply the drag reduction by 0.66 to get the average value of the fuel savings. All the following figures are provided by numerical simulation with DynamiT and all the examples detailed here after have been tried out in “real life”.

2 Applications

The simulations presented hereafter are all related to existing trawls and the figures provided by the simulation software DynamiT have been validated by measurements at sea. They were achieved by the firm Le Drezen, the main French net maker, created in 1829. This net maker is specialised in the design and manufacturing of all types of fishing gears, mainly trawl and purse seine.

2.1 Tropical shrimp trawls : modifying the netting material

The shrimp trawlers of the Indian Ocean are typically 25 to 27 m long with 500 to 750 HP. They tow 2 single or twin trawls (id 2 or 4 trawls). Fuel consumption is around 105 to 125 l/h at 2.7 knots.

Replacing usual PE by dyneema fibre allows a reduction of the towing traction (around 7 tons) of about 20%. A second operation can then be considered : the reduction of door size which leads to the total reduction of the towing traction of around 28% with an increase of the vertical opening leading to an increase of the filtered volume of 20%.

2.2 Cephalopod trawls : modifying the material and the trawl design.

Trawls fishing squid in the Falkland Islands are 70 to 80 m long with 2000 to 3000 HP with a traction capacity of 40 tons. Trawls used have 4 panels with 70 mm meshes. Doors are about 7 m² are 1700 kg. The towing speed is around 4 knots.

The first step in optimisation consists in replacing some PE parts of the trawl by dyneema. The tension reduction is around 20 % (19 tons). The filtered volume remains about the same.

From observation of the behaviour of the netting in the wings from the simulation results, the second step consists in reducing the wings height by 50% (dividing the number of meshes by 2). Thus, we observe an other reduction of the tension of around 14% with a vertical opening remaining almost constant (due to the drag reduction).

Combining these two options leads to a drag reduction of 30% with an increased filtered volume (5%). An other potential drag reduction lies in the door size.

2.3 Twin trawls against single trawl

The considered trawlers are 44 m long and have about 40 tons of towing force. They are able to tow single and twin trawls.

Twin trawls that widely expanded in the 80^{th} in Europe and France allow better catches due to the increased swept surface and relatively reduced towing force needed. The twin trawls performances are very interesting when fish is abundant and on benthic species like monk fish, nephrops, flat fish …

For deep species, a trawl with long wings and a good vertical opening can do as well and even better than twin trawls. The advantages of using a single trawl are obvious : only 2 wires, no “clump”, easier handling …

When comparing the two simulations, the advantage in terms of swept surface and filtered volume is obviously for twins but towing tensions are 27% lower for the single trawl in the example and its performance are nevertheless very good. Consequently, the fishing company has chosen the single trawl for its lower fuel consumption and for its good level of performance. This example is a way of reflexion for fishing companies using twin trawls and looking for a reduction of their fuel consumption.

2.4 Pair trawling : influence of the trawl geometry

The considered trawlers fish hake and operate at about 130 m deep. They are 38 m long with 1500 HP. The distance between the vessels is around 1000 m, the fishing gear is 2000m behind and is towed at the speed of 2 knots.
The rigging is made of 1000 m of 24 mm wire, 500m of 28 mm wire and 600 m of 40 mm mixed. Bridles are 200 m long. Floatation is made of 150 floats of 300 mm. Drums volume is between 18 and 30 cubic meters.

The existing trawl has been optimized in terms of geometry and drag, working on the cutting rates, mesh size and twin diameter. The improvement in terms of tension is 4.7 % with and increasing filtered volume of about 5%. Measurements at sea have confirmed these figures and the trawl performance were beyond the expectations.

2.5 Danish seine : a way to consider

The Danish seine is a technique that started to expand in Denmark in 1822. It has rapidly expanded to neighbouring countries and has been adapted to local fishing conditions. Countries using it are Denmark, Holland, Belgium, Scotland, Ireland, Iceland, Canada, Japan … and France soon ?

The advantages are those of fishing by day because the technique is more efficient at this moment. It can be practiced on 20 to 300 m depth even with a 100 m difference in level. Target fish are haddock, cod, coalfish, whiting … In the case of a 21m long vessel, with 500 HP, working 12 h a day, the fuel consumption is about 500 to 700 l depending on the distance to the fishing area.

Towed Gear Optimisation Application to trawls

Benoît VINCENT, IFREMER
Jean ROULLOT, Ets. Le Drezen

Comment réduire la Consommation en carburant des chalutiers ?

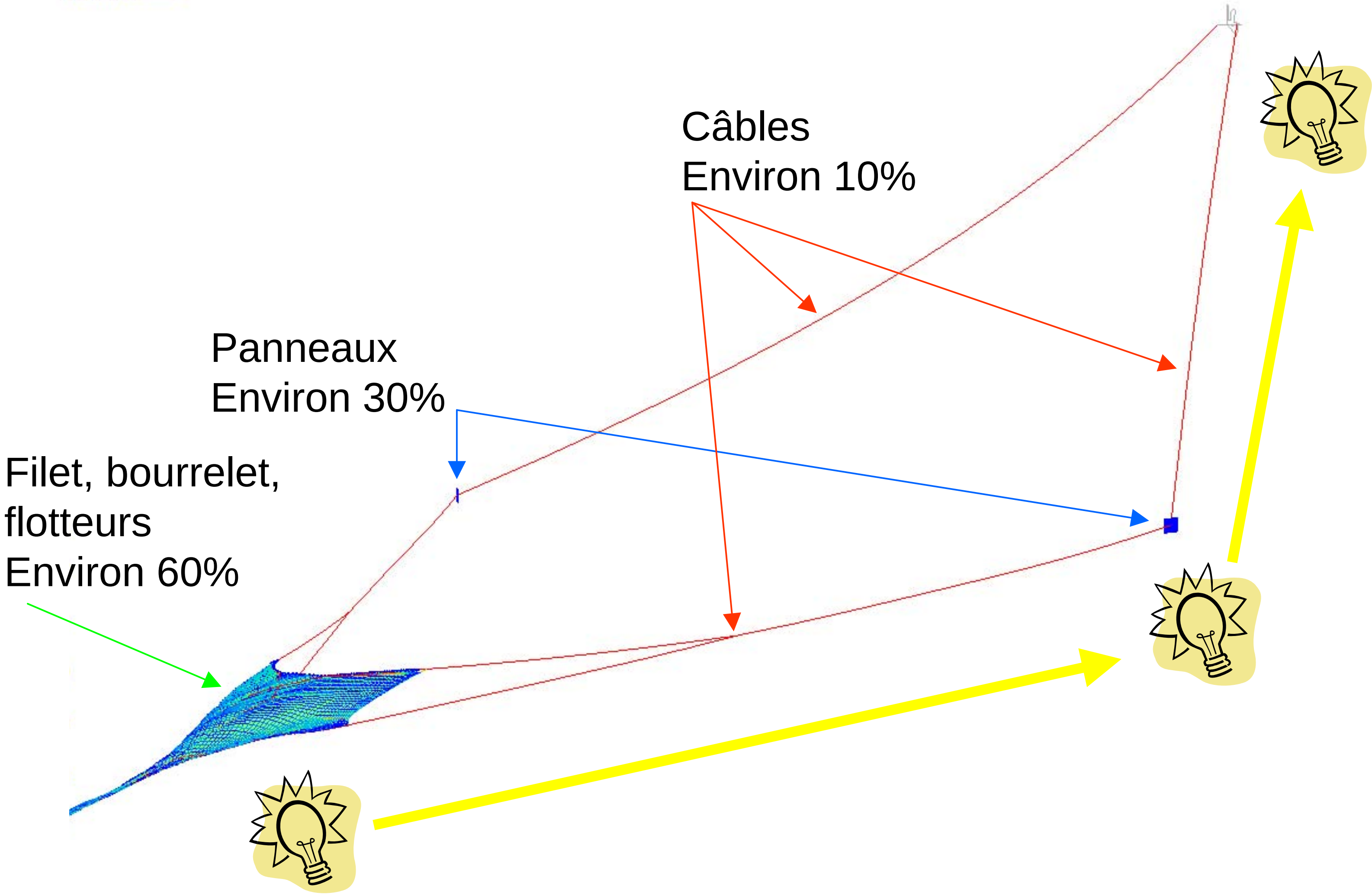
Répartition moyenne de l'utilisation du carburant :

1/3 pour le navire

- route pêche
- propulsion de la carène pendant les opérations de chalutage
- le froid et les auxiliaires

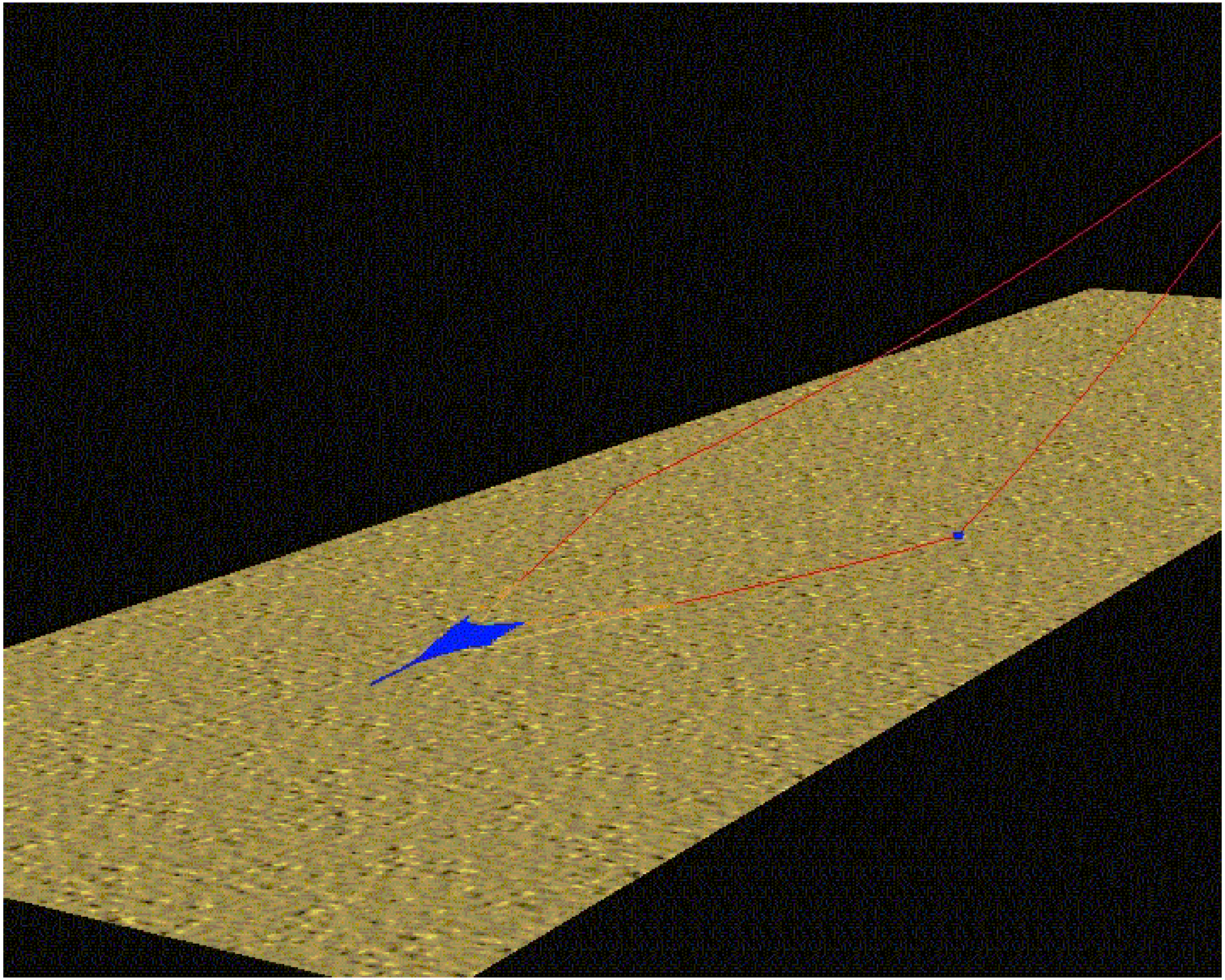
2/3 pour le train de pêche

Sur les 2/3 utilisés par le train de pêche :



Simulation numérique du comportement des chaluts

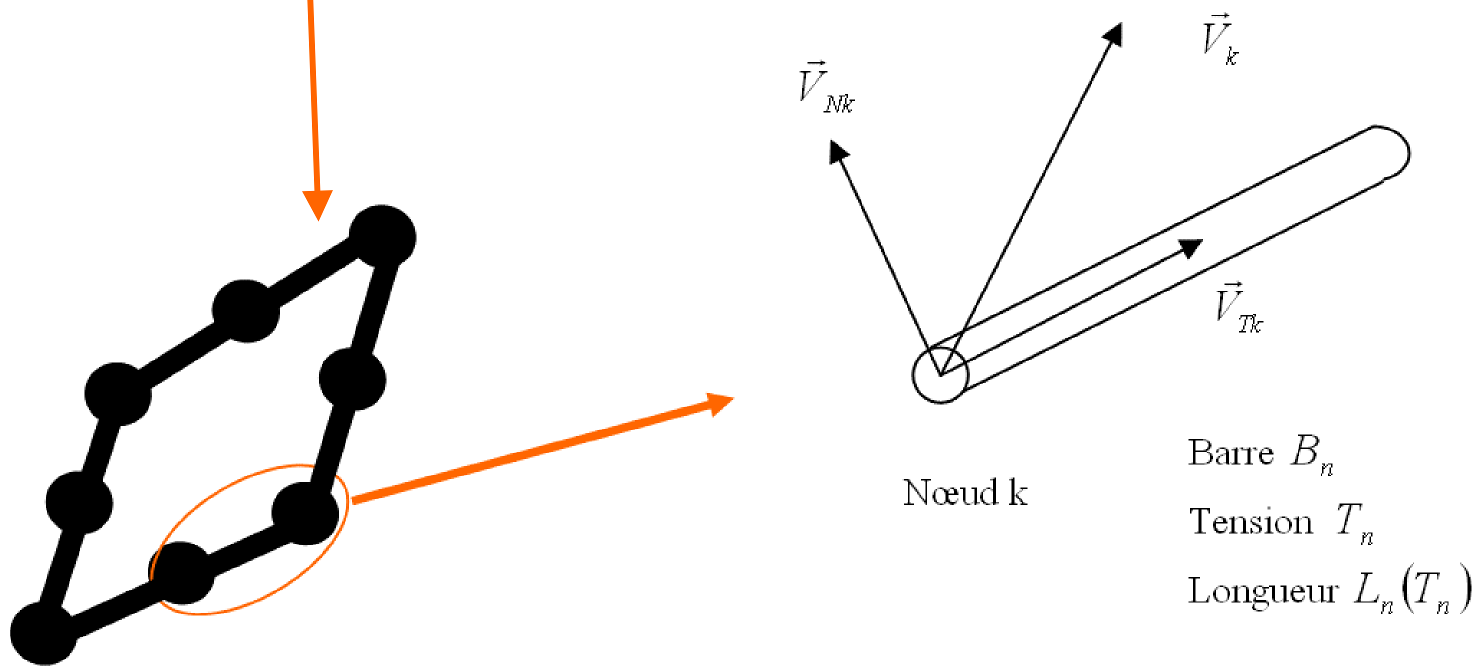
Simulation numérique avec DynamiT



DynamiT

- Trois thèses de doctorat, essais mer, évolution permanente …
- Basé sur un modèle de barres rigides
  « gros » système d'équations non linéaires

Simulation numérique avec DynamiT



Applications principales :

- Compréhension du fonctionnement des chaluts
- Réduction de la consommation de fuel
- Réduction d'impact sur le fond marin
- Dimensionnement d'un chalut
- Formation
- …

Simulation numérique avec DynamiT

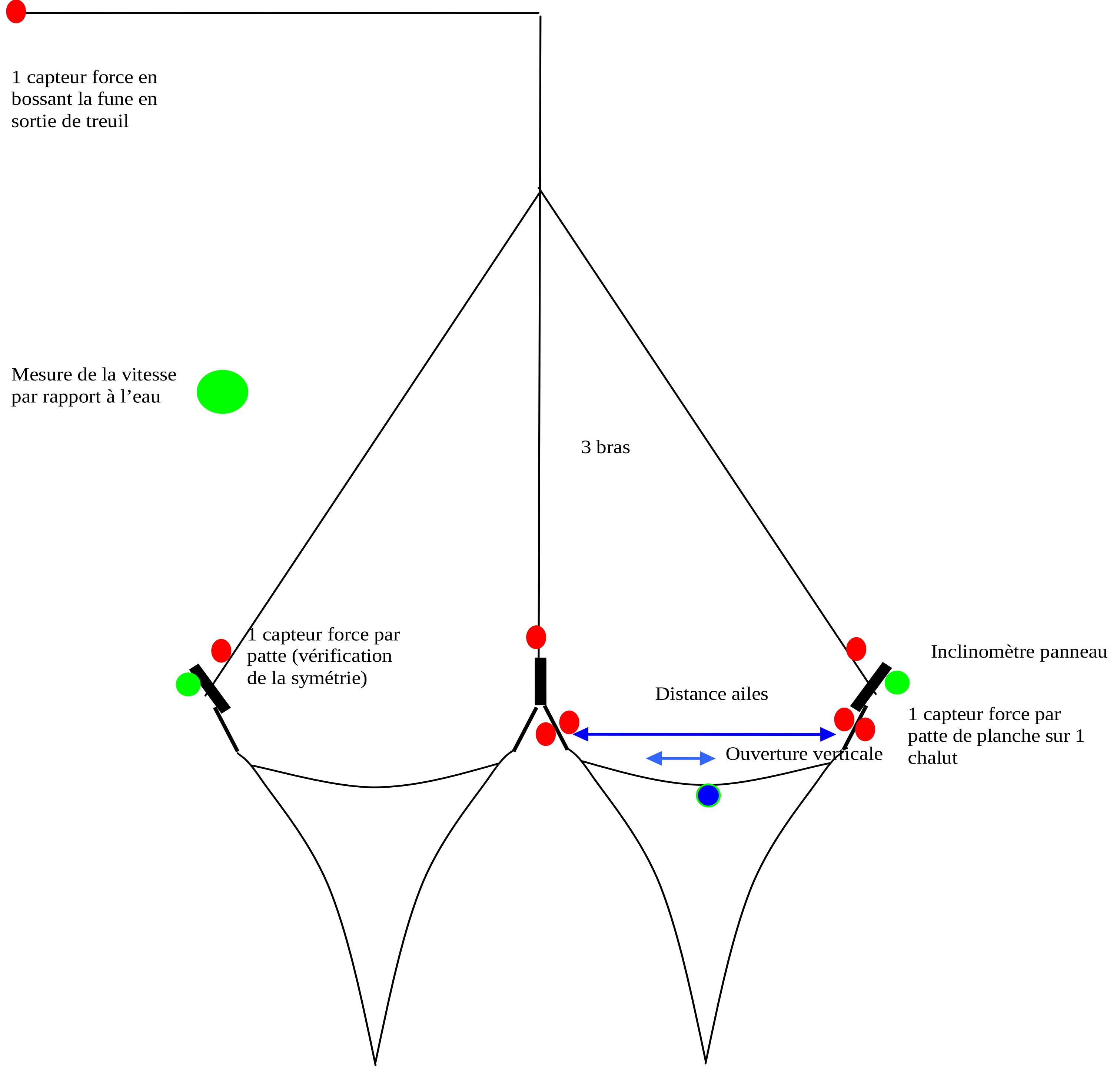
Avantage

- Économique par rapport à des essais mer ou bassin
- Pas d'effet d'échelle (bassin)
- Mettre en équations c'est comprendre

Principaux utilisateurs

- Instituts de recherche
- Fabricants de chaluts
- Armements
- Formation

Validation des simulations par la mesure


1 capteur force en bossant la fune en sortie de treuil
Mesure de la vitesse par rapport à l’eau
3 bras
1 capteur force par patte (vérification de la symétrie)
Inclinomètre panneau
Distance ailes
1 capteur force par patte de planche sur 1 chalut
Ouverture verticale


VALEPORT
VALEPORT

Quelques cas concrets …

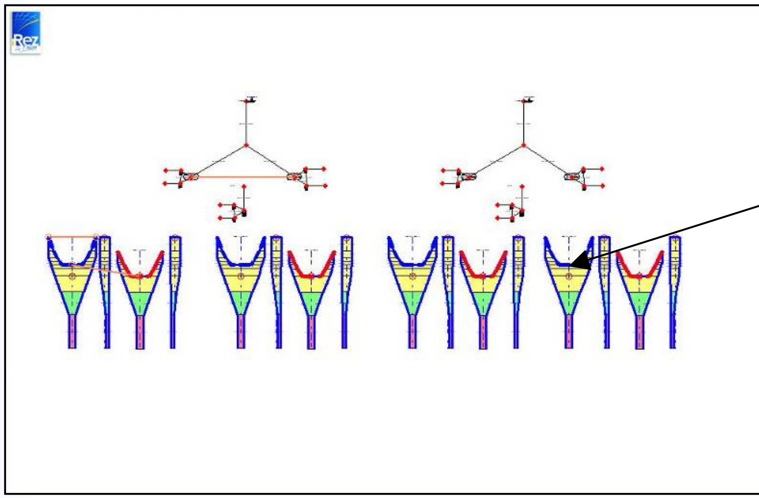
Applications des Ets. Le Drezen

Chaluts à crevettes

19,20 m x 23,70 m

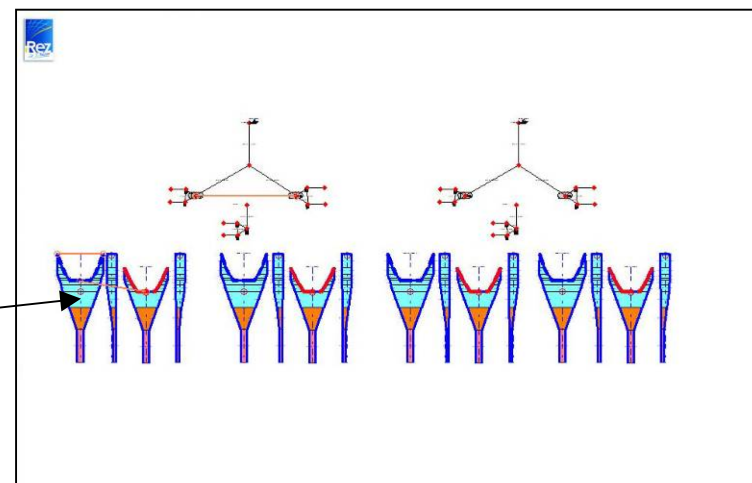
Influence du matériau et de la taille des panneaux

Chaluts à crevettes - Remplacement du polyéthylène par du dyneema

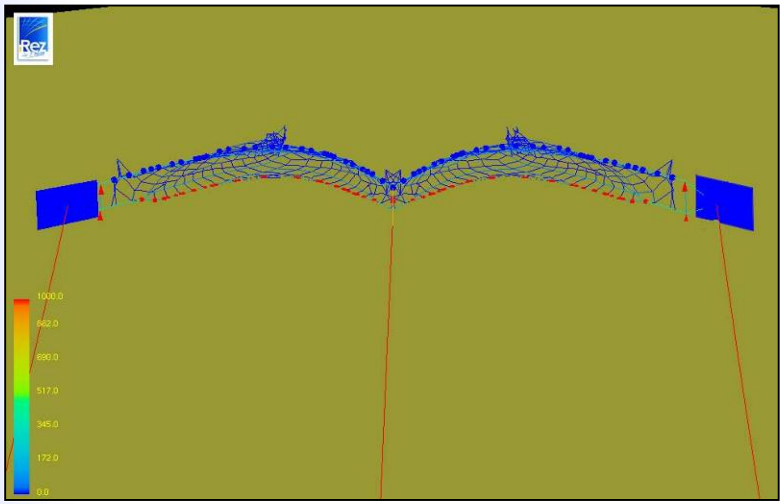
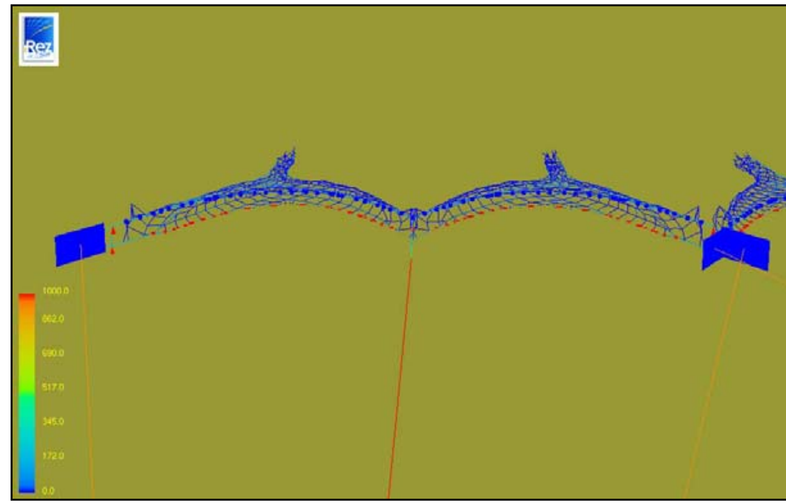


Polyéthylène 2 mm

Dyneema 1 mm

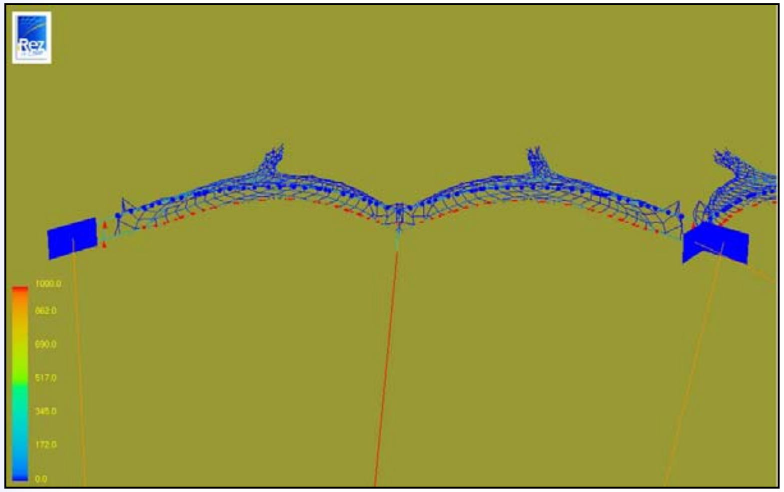


Chaluts à crevettes - Remplacement du polyéthylène par du dyneema

Chalut en polyéthylène	Chalut en dyneema
	
Ouverture verticale : 1,8 m	Ouverture verticale : 1,5 m
Ouverture horizontale : 10,7 m	Ouverture horizontale : 13,7 m
Écartement panneaux : 23,4 m	Écartement panneaux : 30,1 m
Volume filtré : 96 500 m^3/h	Volume filtré :102 500 m^3/h **(+6,2%)**
Tensions : 7360 kg	Tensions : 5790 kg **(- 21,3%)**

Chaluts à crevettes en dyneema – Réduction de la superficie des panneaux

Panneaux 4,48 m^2



Ouverture verticale : 1,5 m

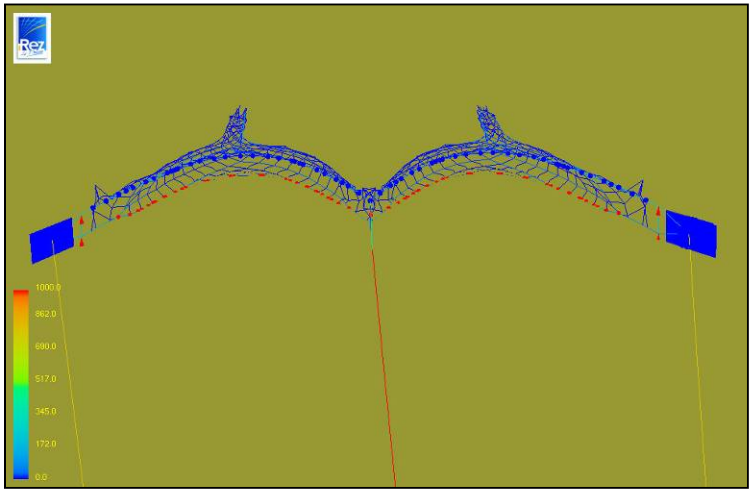
Ouverture horizontale : 13,7 m

Écartement panneaux : 30,1 m

Volume filtré : 102 500 m^3/h

Tensions : 5 790 kg

Panneaux 3,44 m^2



Ouverture verticale : 1,9 m

Ouverture horizontale : 12,2 m

Écartement panneaux : 26,7 m

Volume filtré : 115 500 m^3/h **(+12,7%)**

Tensions : 5 300 kg **(- 8,5%)**

Récapitulatif des résultats de simulation chaluts à crevettes

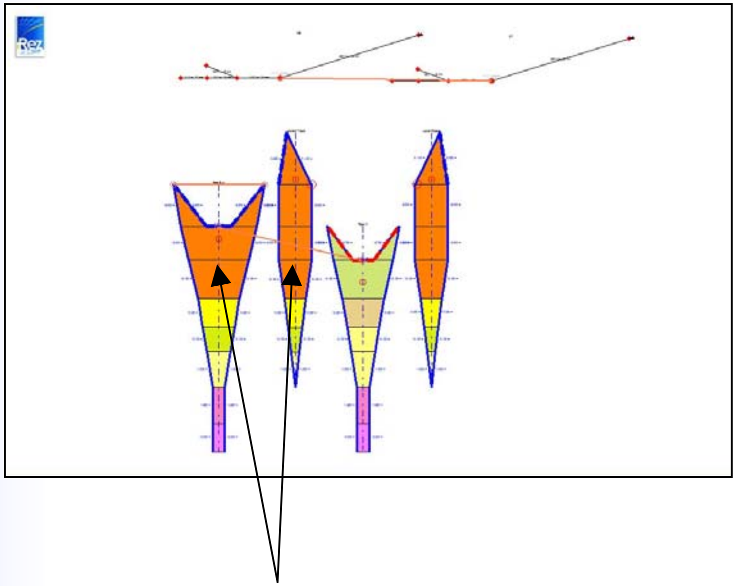
Matériau et gréement	Polyéthylène	Dyneema	Dyneema – panneaux réduits
Ouverture verticale	1,8 m	1,5 m	1,9 m
Ouverture horizontale	10,7 m	13,7 m	12,2 m
Écartement panneaux	23,4 m	30,1 m	26,7 m
Volume filtré	96 500 m^3/h	102 500 m^3/h	115 500 m^3/h
%		**+ 6%**	**+19,6%**
Tensions	7 360 kg	5 790 kg	5 300 kg
%		**- 21,3%**	**- 28%**

Chalut à céphalopodes 67,50 m x 90,10 m

Influence du matériau et de la géométrie

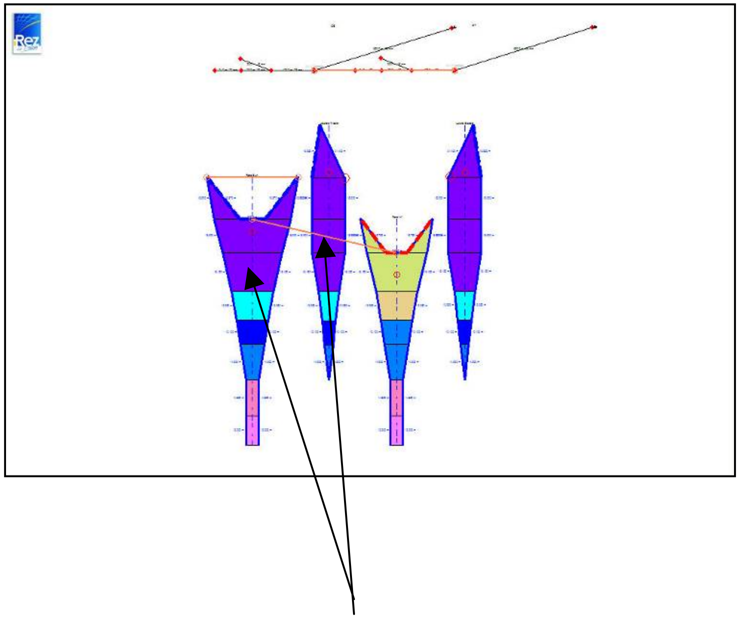
Chalut à céphalopodes 67,50 m x 90,10 m

Polyéthylène



diamètre 4 mm

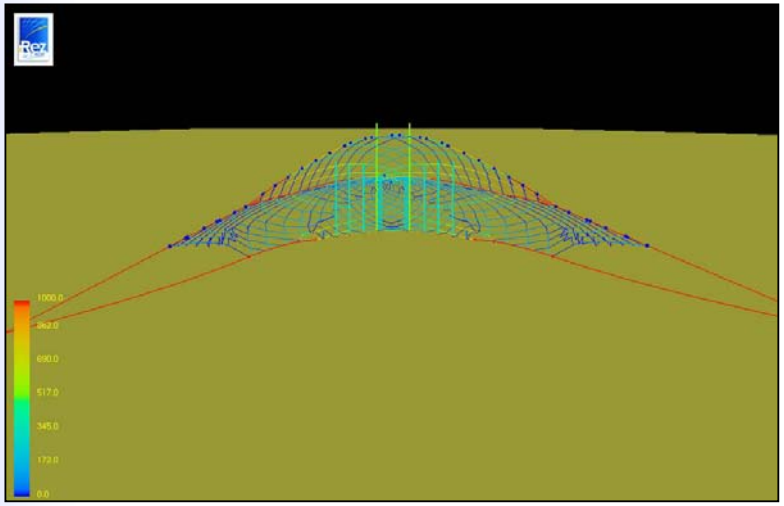
Dyneema



diamètre 2,3 mm

Chalut à céphalopodes 67,50 m x 90,10 m

Polyéthylène



Ouverture verticale : 9,3 m

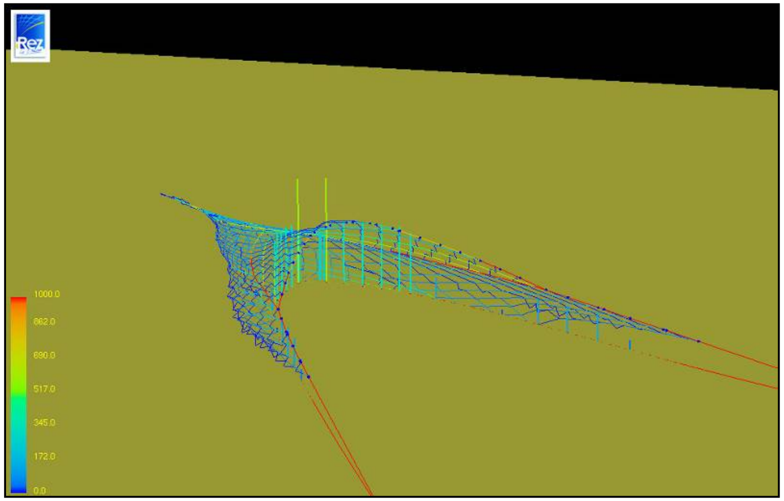
Ouverture horizontale : 23,2 m

Écartement panneaux : 70,3 m

Volume filtré : 1 592 720 m^3/h

Tensions : 24 300 kg

Dyneema



Ouverture verticale : 8,2 m

Ouverture horizontale : 26,1 m

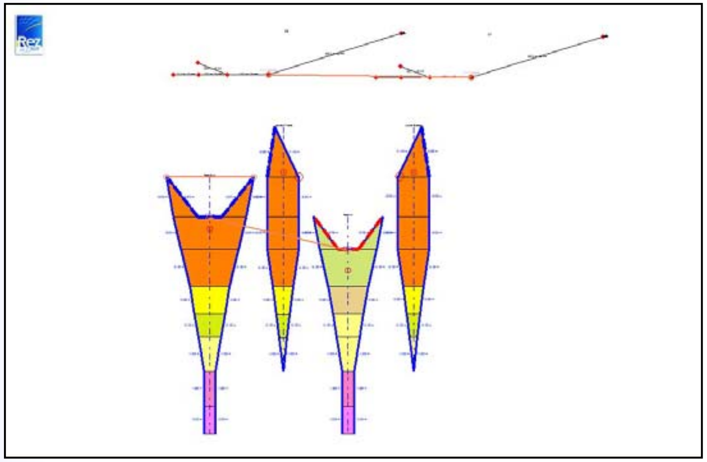
Écartement panneaux : 86,2 m

Volume filtré : 1 584 400 m^3/h

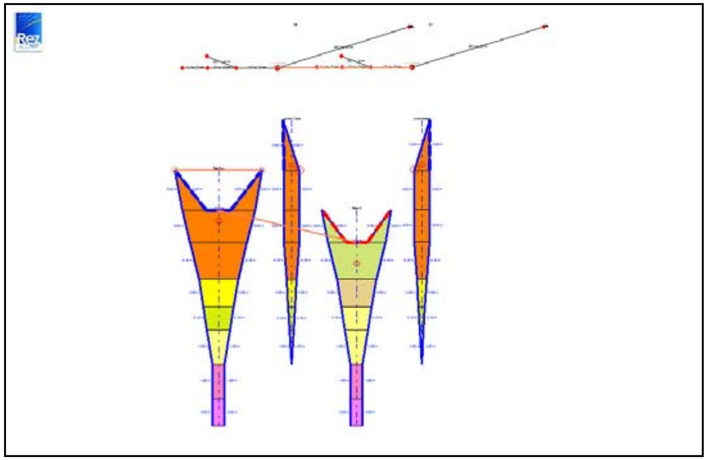
Tensions : 19 100 kg **(-21%)**

Chalut à céphalopodes 67,50 m x 90,10 m

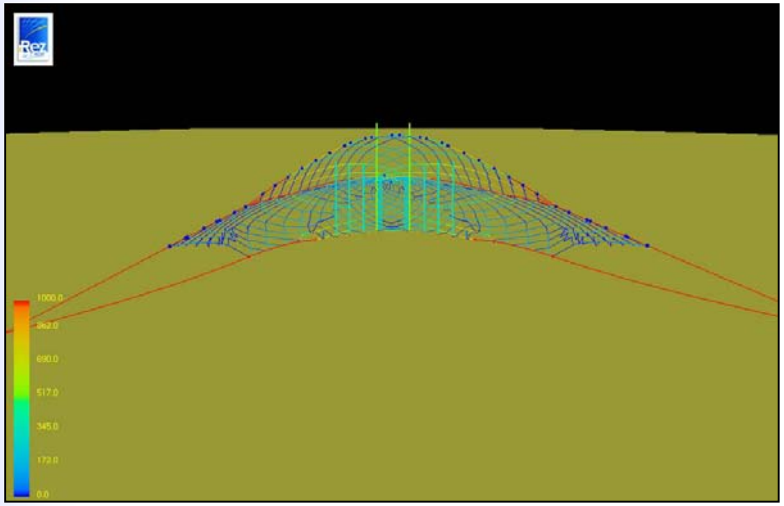
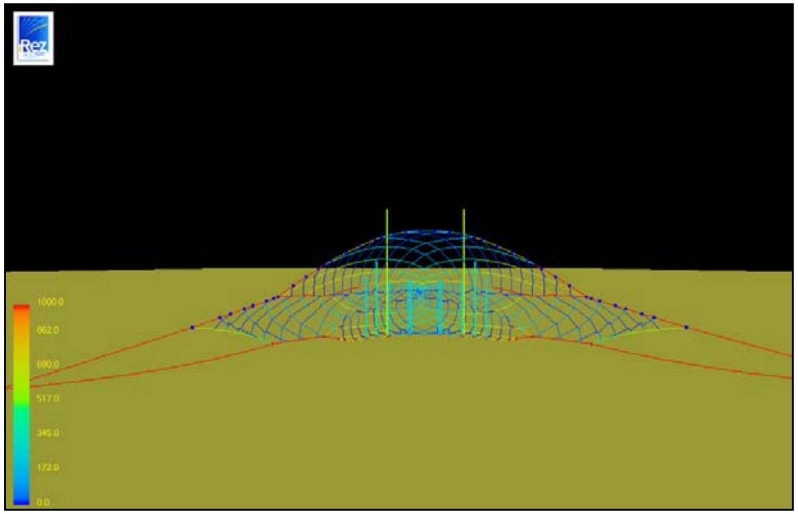
Polyéthylène



Ailes coupées polyéthylène

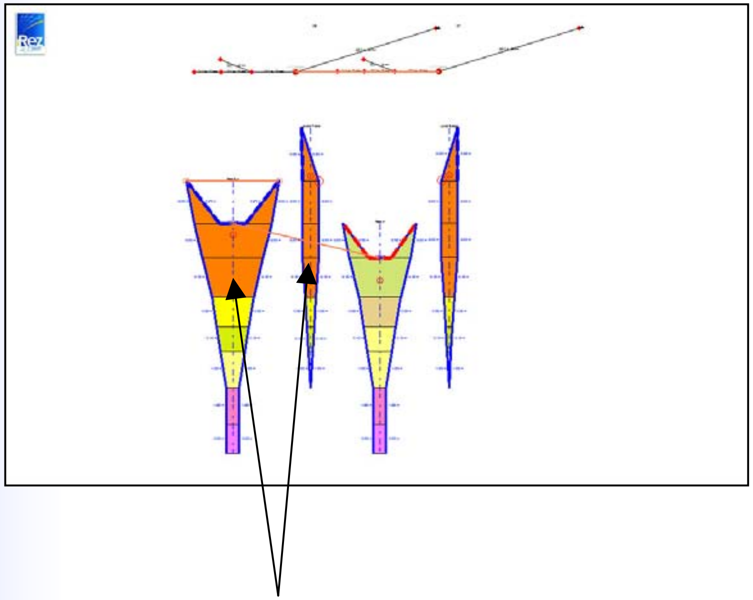


Chalut à céphalopodes 67,50 m x 90,10 m

Polyéthylène	Ailes coupées polyéthylène
	
Ouverture verticale : 9,3 m	Ouverture verticale : 9,6 m
Ouverture horizontale : 23,2 m	Ouverture horizontale : 22,3 m
Écartement panneaux : 70,3 m	Écartement panneaux : 77,4 m
Volume filtré : 1 598 720 m^3/h	Volume filtré : 1 585 312 m^3/h
Tensions : 24 300 kg	Tensions : 20 750 kg **(-14,6%)**

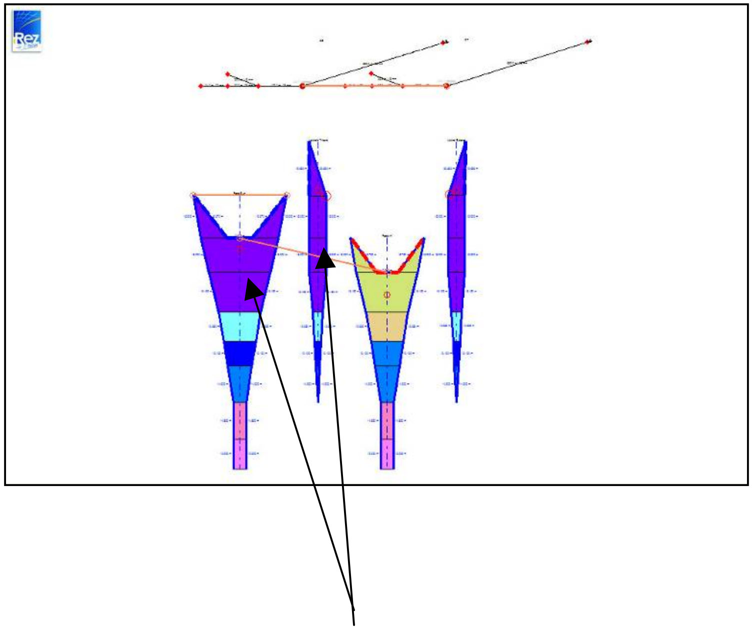
Chalut à céphalopodes 67,50 m x 90,10 m

<u>Ailes coupées Polyéthylène</u>



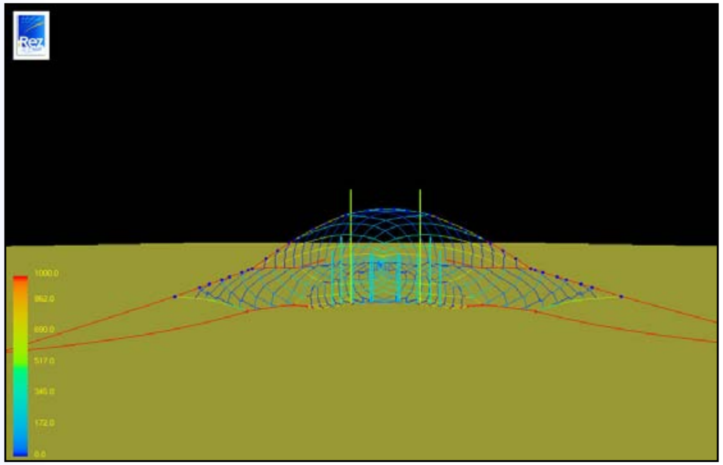
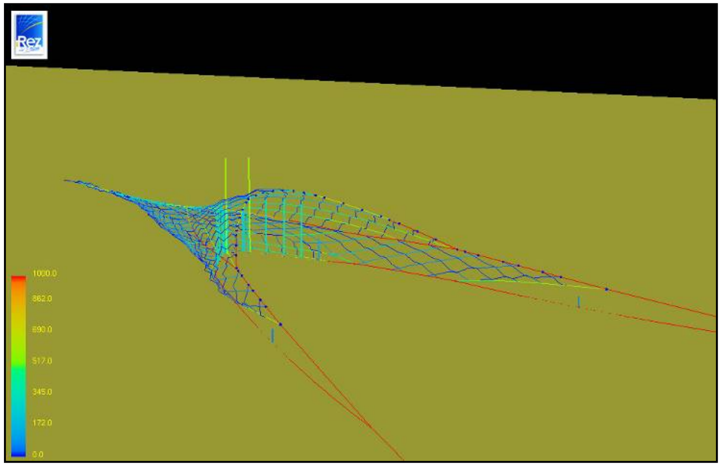
diamètre 4 mm

<u>Ailes coupées dyneema</u>



diamètre 2,3 mm

Chalut à céphalopodes 67,50 m x 90,10 m

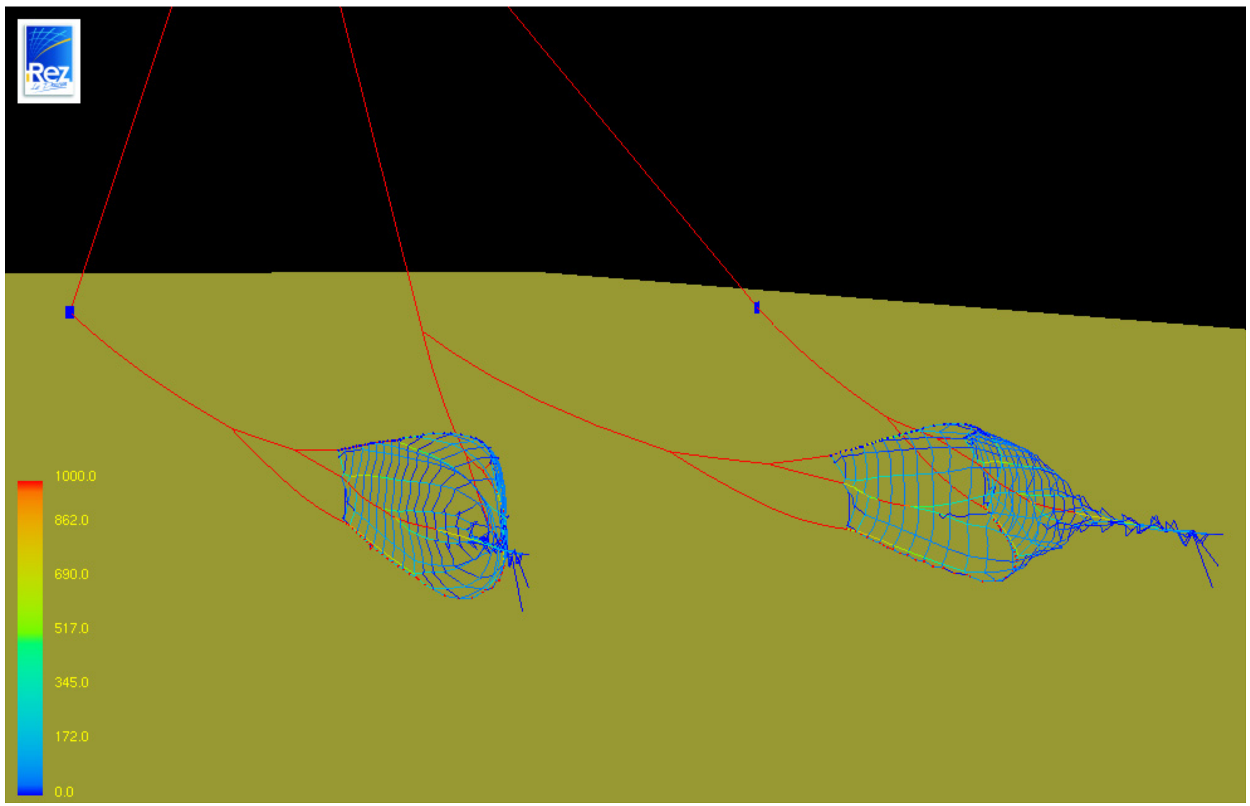
Ailes coupées polyéthylène	Ailes coupées dyneema
	
Ouverture verticale : 9,6 m	Ouverture verticale : 8,9 m
Ouverture horizontale : 22,3 m	Ouverture horizontale : 25,3 m
Écartement panneaux : 77,4 m	Écartement panneaux : 97,2 m
Volume filtré : 1 585 312 m^3/h	Volume filtré : 1 666 800 m^3/h **(+5,1%)**
Tensions : 20 750 kg	Tensions : 16 880 kg **(-18,6%)**

Récapitulatif des résultats de simulation chalut à céphalopodes

Matériau et géométrie	Polyéthylène	Polyéthylène ailes coupées	Dyneema	Dyneema ailes coupées
Ouverture verticale	9,3 m	9,6 m	8,2 m	8,9 m
Ouverture horizontale	23,2 m	22,3 m	26,1 m	25,3 m
Écartement panneaux	70,3 m	77,4 m	86,2 m	97,2 m
Volume filtré	1 592 720 m^3/h	1 585 312 m^3/h	1 584 400 m^3/h	1 666 800 m^3/h
%				**+4,6%**
Tensions	24 300 kg	20 750 kg	19 100 kg	16 880 kg
%		**- 14%**	**- 21%**	**- 30%**

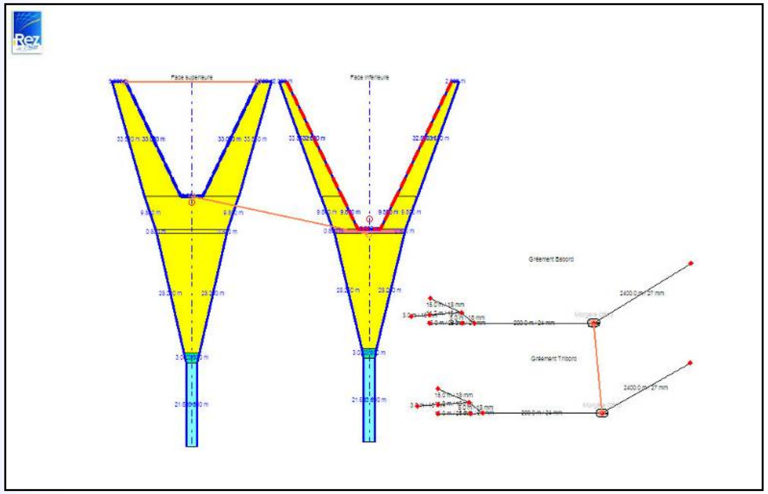
Chaluts jumeaux 35 m GOV et solo 72 m IR

Influence du type de chalut sur les tensions

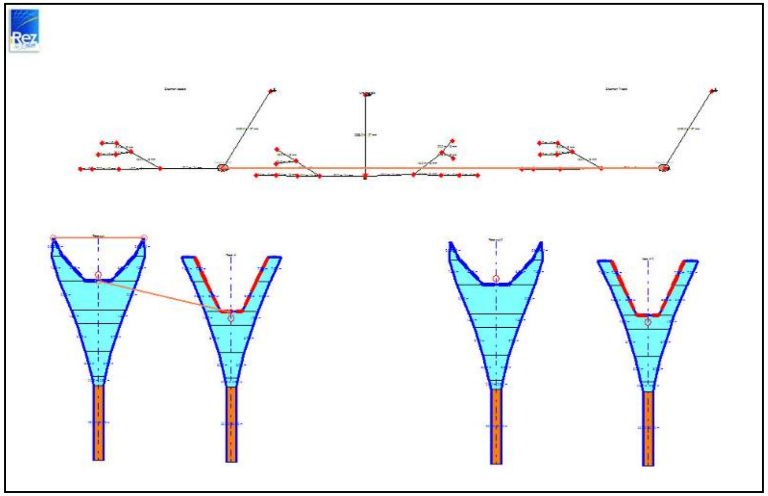


Chaluts Jumeaux et Solo

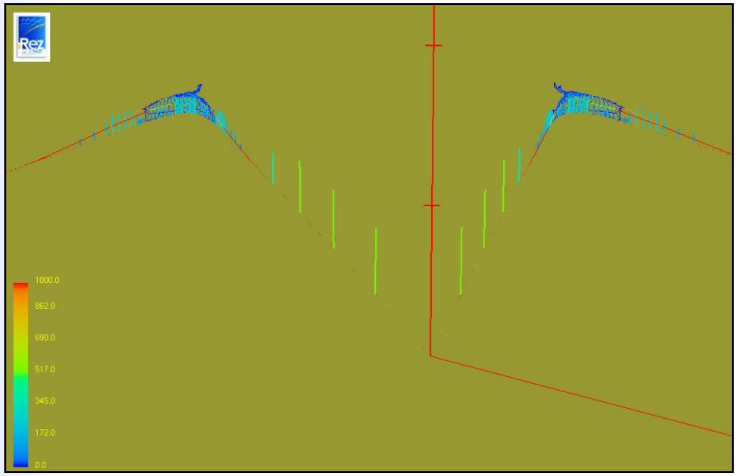
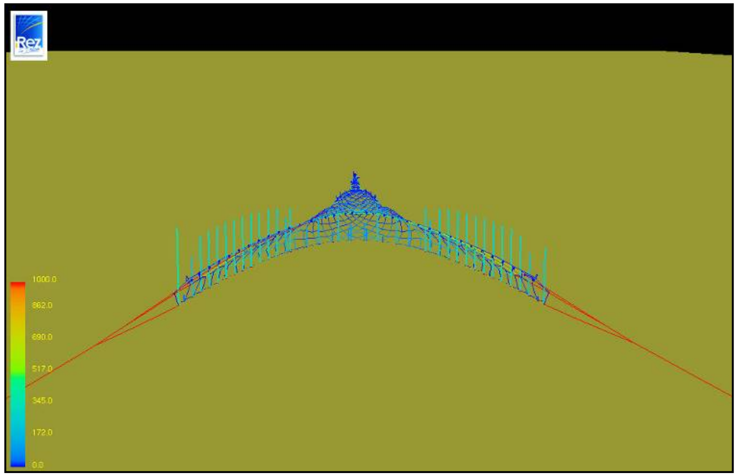
Solo 72 m IR



Jumeaux 35 m GOV



Chaluts Jumeaux et Solo

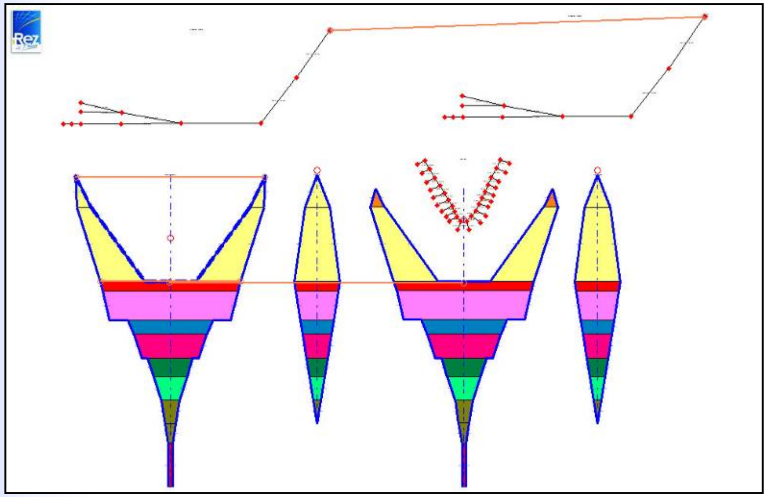
Jumeaux 35 m GOV	Solo 72 m IR
	
Ouverture verticale : 6,3 m	Ouverture verticale : 4,7 m
Ouverture horizontale : 18,3 m x 2	Ouverture horizontale : 32,2 m
Écartement panneaux : 245,1 m	Écartement panneaux : 138,1 m
Volume filtré : 1 277 880 m³/h	Volume filtré : 838 956 m³/h **(- 34%)**
Tensions : 19 470 kg	Tensions : 14 160 kg **(- 27%)**

Chalut bœuf de fond

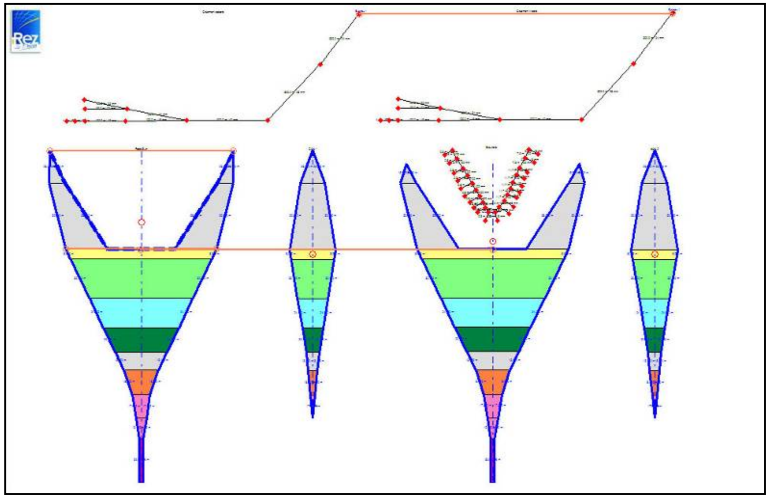
Influence de la géométrie sur les ouvertures et les tensions

Chalut bœuf de fond

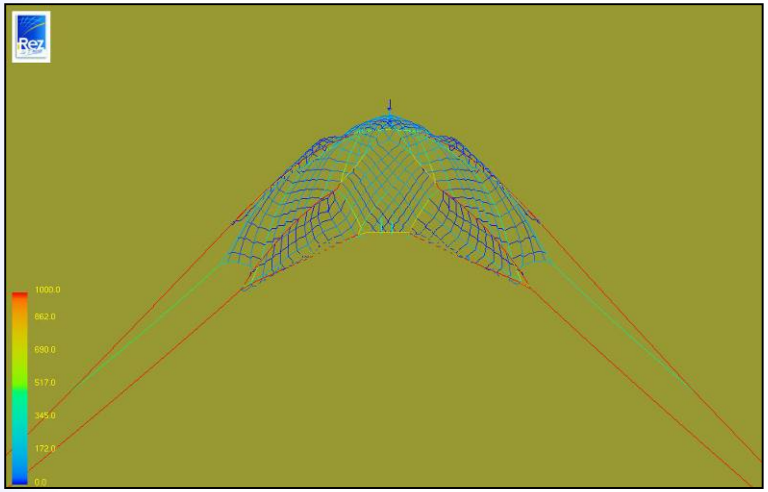
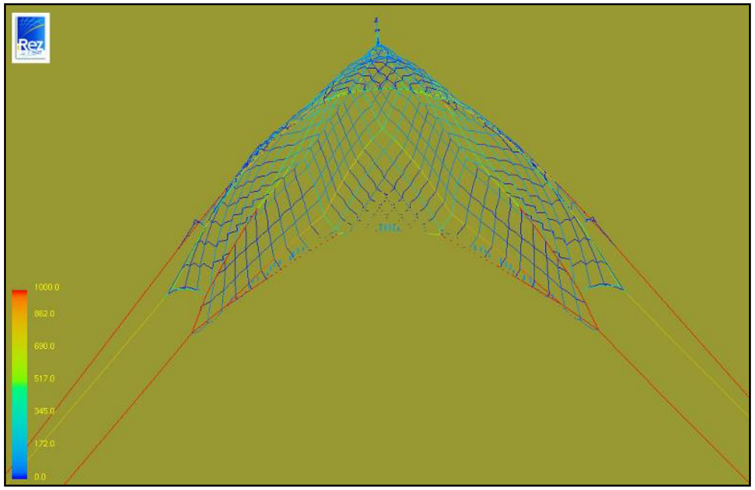
<u>Ancien modèle</u>



<u>Nouveau modèle</u>

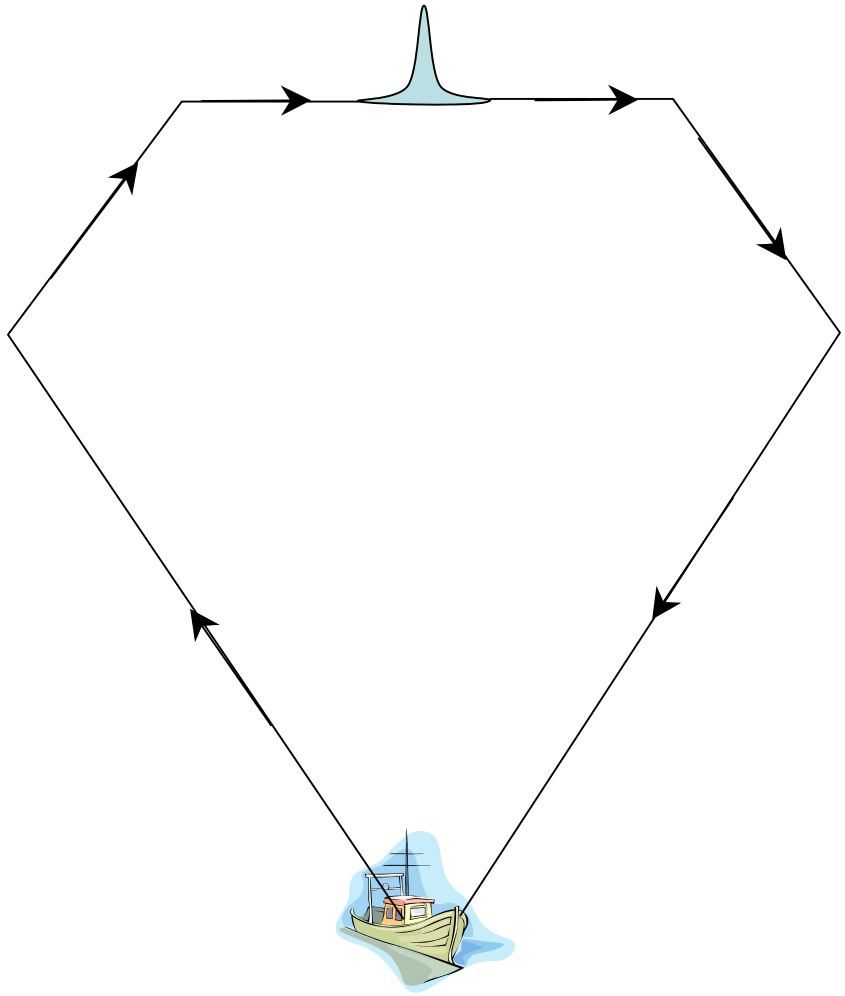


Chalut bœuf de fond

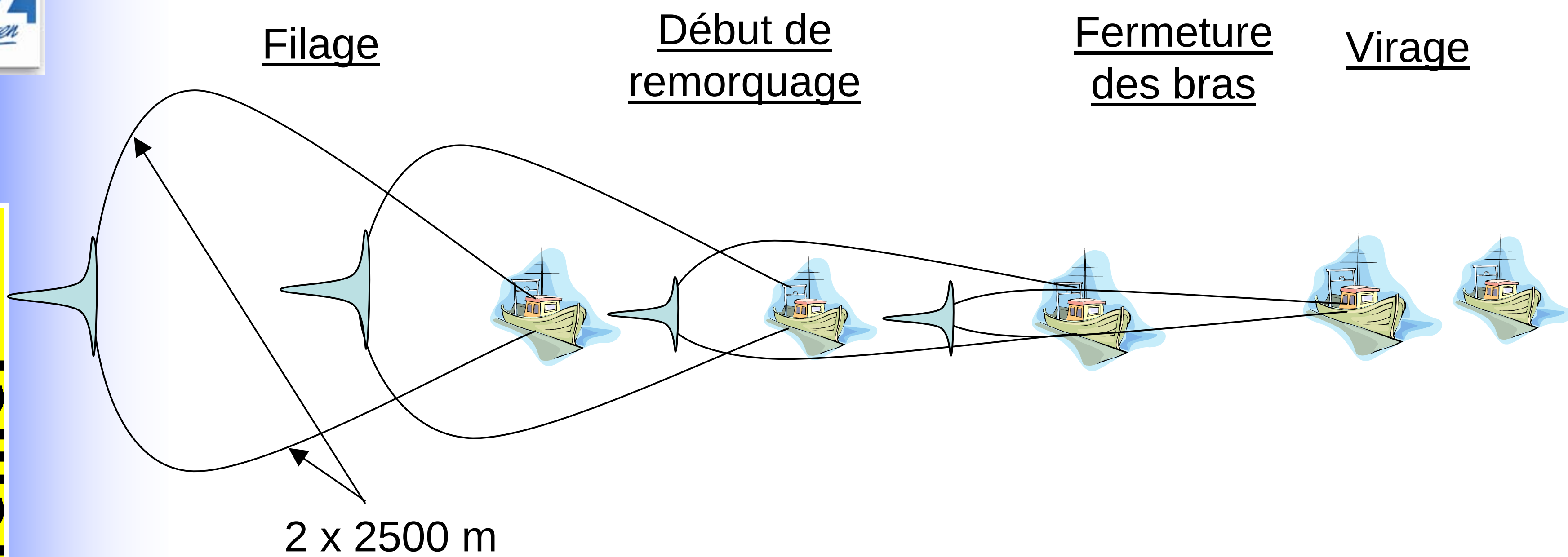
Ancien modèle	Nouveau modèle
	
Ouverture verticale : 37,8 m	Ouverture verticale : 39,9 m
Ouverture horizontale : 96,6 m	Ouverture horizontale : 96,4 m
Distance des bateaux : 1000 m	Distance des bateaux : 1000 m
Volume filtré : 13 523 304 m^3/h	Volume filtré : 14 245 584 m^3/h **(+5,3%)**
Tensions : 15 090 kg	Tensions : 14 380kg **(- 4,7%)**

SENNE DANOISE

Senne Danoise



Senne Danoise



Surface balayée :

Senne danoise (1h 40mn) : 1 074 480 m^2

Chalutage classique (1h 40mn) : 463 920 m^2 **(- 56%)**