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Performance of a trawl codend made from 90º turned netting (T90) compared with that of traditional codends

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Abstract

This paper describes a series of tests conducted in the SINTEF Flume Tank with different designs and constructions of codends. The principal aim was to disclose the performance of a codend where part of the netting was turned 90° (called T90) and compare it with codends made from netting stretched in the normal direction. Measurements of cross section, water flow, and turbulence were taken and the dependency of towing speed and catch size was determined. It is concluded that the T90 codend must be superior to standard codends in many ways: preservation of fish quality, selectivity, survival rate of escapees, efficiency and strength.

Introduction

It is interesting to note the share of attention, which has been given the trawl codend over the time from the commercial side; it is very small. It is after all the bag, where the whole catch will be collected. Some consideration has been given to the strength of the material, and to how to protect the netting from being worn by the seabed and by being taken in over the ramp on stern trawlers. Water flow trough the codend, height above seabed, shape, impacts on fish quality and other aspects have not generated much interest. The main interest comes from the fisheries management side and deals with the selective properties of codends as a function of netting materials, mesh-sizes, protecting bags etc.

Background

Work has been going on at DIFTA in the North Sea Centre Flume Tank since 1994 on the performance of different designs of trawl codends (Hansen et al. 1996). The background was the interest in designing a codend, which could preserve as much as possible of the live fish quality. The fact is, that the deterioration of fish quality from catch to consumer starts in the codend. It has long been observed on underwater video recordings that codends are swaying due to the turbulence found in the water in front of and behind the catch. The same turbulence causes the fish to be thrown from side to side. This contact against the netting causes removal of scales and mucus as well as subcutaneous bruises and pressure marks.

The damages to the skin might not be highly visible and might not show up when the fish is displayed at the first-hand sale. The problems arise at later stages and the shelf life is significantly lower.

The present study is based on tests from 1994 – 95 and comprises a more detailed study of the performance of selected codends. These results have never been made public. A brief résumé is found below.

The aim at that time was also to develop a quality preserving codend. The hypothesis was that the best codend was one with a large cross-section area and one with a low swinging action. It was believed that the movements of a codend as seen on underwater recordings of trawls were caused by turbulence just in front of and behind the catch. 12 different designs of codends were tested in the flume tank in half scale. The test set-up was simulating that of a rear part of a whitefish trawl. The model codend and a few meters of the rear part of a trawl belly was attached to a ring having approximately the same diameter as a full scale trawl.

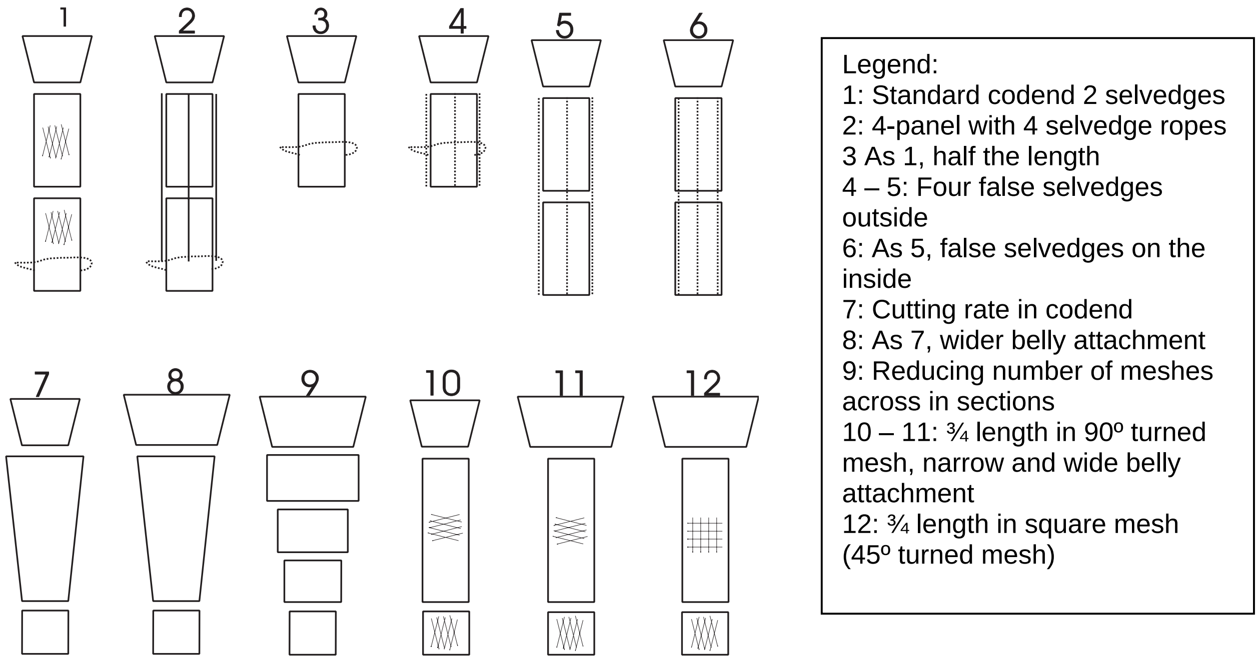
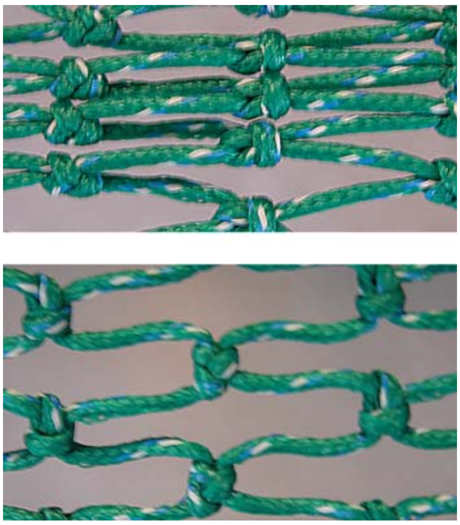


Figure 1 Draft specifications of 12 different codend designs tested in half scale in Flume Tank

The study was designed to gain information about how basic design principles affected the geometry like cross-section and the movement of codends. Following parameters were considered:

- Length of codend.
- Number of selvedges, 1, 2 and 4.
- Placement of selvedges (inside – outside).
- Attachment point (at the point of mesh for mesh or further forward in the trawl, where the cross section (and number of meshes) is larger.
- Cutting rate along the side.
- Decreasing number of meshes in every section as you move aft towards the codline.
- Orientation of the net, standard or turned 45º (square mesh) or 90º.

Figure 2 Close up of netting with horizontal stretch, upper: normal; lower: turned 90º, T90



The codends were built in scale 1:2. The specification of the full-scale codend was that of a traditional Danish codend for whitefish:

- Lifting bag: 8 m long in 120 mm full mesh, 4 mm double braided PET
- Extension piece: 8 m long in 120 mm full mesh, 4 mm single braided PET

The tests were done at a speed of 2.5 knots with a simulated catch of 400 kg. The ‘catch’ was made from water-filled plastic bags, each holding 0.5 l. The following observations and measurements were documented:

- Number of sideways swings in 5 minutes.
- Maximal amplitude.
- Height of codend at the entrance to the codend.

One of these codends gave remarkably better results than other in terms of cross-section area and movements: - the codend with 90º turned net mounted on a wide belly section, here called T90. It should be noted, however, that the codend with square mesh (netting turned 45º) also had a large cross-section, but had medium amplitude.

It was anticipated that the breaking strength of the T90 net was smaller than ordinary turned netting. Measurements in a test bench proved different. Breaking tests done at DIFTA and other laboratories have shown that – depending on type of material and construction – T90 net is around 5 – 15% stronger (Moderhak 2000 a)

In September 2004 a seminar was held in Hirtshals funded by the Nordic Council. The results of the above project were presented, and SINTEF decided to apply for funding for a more thorough study of codend properties based on the findings mentioned above.

This study is part of a large project on "The Relationship between Fishing Gear and Fish Quality", funded by the Norwegian Fishery and Aquaculture Research Fund. The aim of the present investigation have been to reveal more information about the performance of different designs and constructions of codends and to find the dependency of catch size and towing speed. It is anticipated that the project will continue in the fall of 2004, where a T90 codend in full scale will be compared to a standard codend. A number of fish quality parameters will be studied.

Materials and Methods

Table 1 gives the details of the construction of the model codends tested in this study:

Table 1 Construction of the tested codends

	Standard 2 selvedges	Standard 4 selvedges	T90 extension, standard lifting bag, 1 selvedge
Extension piece			Turned 90º
Length, no. of #	99½	99½	99½
Width, excl. selvedge, no. of #	2 x 47	4 x 22	1 x 94
Mesh size, mm. full mesh	60	60	60
Material	1.8 mm braided PET	1.8 mm braided PET	1.8 mm braided PET
Lifting bag			
Length, no. of #	34½	34½	34½
Width, excl. selvedge, no. of #	2 x 47	4 x 22	1 x 94
Mesh size, mm. full mesh	60	60	60
Material	2.3 mm braided PET	2.3 mm braided PET	2.3 mm braided PET

Water – vacuum packed in plastic bags – was used to simulate a catch of fish. The bags held 0.5 l water each. Most tests were done with a ‘catch’ of 50 kg, some with 100 and 150 kg.

The models can simulate a range of full-scale codends. Table 2 gives two examples.

Table 2 Full-scale values for the tested models

Item	Model value	Scaling ratio 1:2	Scaling ratio 1:3
Mesh size	60 mm	120 mm	180
Material	1.8 mm braided	3.6 mm	5.8 mm, (equals double 4 mm)
	2.3 mm braided	4.6 mm	6.9 mm, (equals double 5 mm)

The codends were mounted on a circular frame 1 m in diameter. The frame was attached to towing masts upstream in the flume tank.

The following configurations for the codends were selected:

1 Standard codend with 1 selvedge on the outside
2 Standard codend with 2 selvedges on the outside
3 Standard codend with 2 selvedges on the inside (turned inside out)
4 Standard codend with 4 selvedges on the outside
5 Standard codend with 4 selvedges on the inside
6 T90, ¾ of the length the net turned 90º, the rest – the lifting bag: ordinary stretched netting

Furthermore it was also tried to “point” (or drop shape) the codend in an attempt to utilize a normal way to reduce towing resistance in a towed body.

7 Alaska knot on standard codend with 2 selvedges on the outside
8 Alaska knot on T90

9 Netting triangle (cone) on standard codend with 2 selvedges on the inside
10 Netting triangle on T90

11 Canvas cone on standard codend with 2 selvedges on the outside
12 2/3 canvas cone on standard codend with 2 selvedges on the outside
13 1/3 canvas cone on standard codend with 2 selvedges on the outside

14 T90 with small meshed liner inside
15 T90 with a half sphere of canvas inside

The *Alaska knot* is a method of closing the net by tying together the upper and lower meshes from top and bottom panel. The result is a long knot across the width of the codend.

The *netting triangle* was made from two triangles on netting mounted on the rear meshes of the top and bottom panels. The triangles were cut along a bar on the sides.

The *canvas cone* was a circular cone mounted on the widest point of the codend. Cutting away 1/3 gradually reduced the cone in configuration 11 and 12.

The *small meshed liner* was made from plankton netting, 1 x 0,5 mm.

The *half sphere* was made from canvas with the diameter of a codend full of catch.

The following measurements were taken:

Geometry: Height and width at narrowest point of the entire codend

Swings: The swinging action of the codend was documented as a graphic presentation of the movements over 5 minutes: A transparent plastic sheet was mounted on a TV monitor showing the picture from a front-mounted camera pointed at the codend. A specific point at the codend was selected and the movements over 5 minutes were tracked with a pen.

Resistance: 4 load-cells were inserted in the wires holding the codend frame.

Water flow: A flow meter was used to measure the water flow through the codend at intervals from front to rear end.

It should be noted here, that in full scale, the lifting bag will be made from knotless netting, because this kind of netting has a smooth inner surface, which will damage fish skin much less than ordinary knotted netting. Therefore, the lifting bag in the T90 model codend is made from ordinary turned netting, as the stretching properties of this resembles better knotless netting than do T90 netting.

Results

Geometry

The model values of the measurements of the height and width of a selection of codends are given in table 3. The area is calculated for an ellipse having the measured height and width as axes. Note that the measurements are model values.

Table 3 Geometry at narrowest point of different codends

Ref. no.	Codend construction	Height cm	Width cm	Area cm^3
1	Standard 1 selvedge	13	23,5	240
2	2 outer selvedges	9,7	31,7	242
3	2 inner selvedges	25,7	31,2	630
9	2 inner selvedges and netting cone	29,3	33,5	771
4	4 outer selvedges	20,7	27,3	444
5	4 inner selvedges	28,2	28	620
6	Extension: T90, lifting bag: ordinary	56,2	65	2869

The reference numbers refers to the list on page 5 and the numbers in the appendix

Swinging / Occilation
Not all codends were used in recording the moving action in the flow. Appendix 1 shows most of those, which were studied for construction differences.

The swinging of the codends was mostly in the form of a side-to-side movement gradually going over to up-and down. Thus over time a full circle was covered. There was a huge variation in circle diameter among the various codends: from less than 25 cm (with T90 and Alaska tying knot, no. 8) to around 2 m (with 2 selvedges, no. 2). However, some codends that showed big movements were moving around very slowly without throwing the fish around. The recordings on the video monitor do not distinguish clearly between the turbulent movement and the more slow ones.

The T90 codend showed a remarkably lover movement than the standard codends with 2 or 4 selvedges. The plastic bags inside were also seen to be almost fixed in their position. This was in strong contrast to what was seen in the standard codends where the bags were thrown around.

Pointing the net with an Alaska knot or with a netting cone reduces the movement to some extent. But for some reason this does not work with a canvas cone. On the contrary this attachment increased the movements. In the beginning it was thought that it was because it was closed in the rear, but cutting off first 1/3 and later 2/3 did not improve the situation.

Giving the codend a "watertight" rear part by inserting a canvas half sphere makes the codend move more than standard codends normally do. Also, the "fish" inside are seen to be thrown from side to side.

Inserting a small-meshed liner in the T90 codend seems to make the codend very stable, in fact this was the most stable codend of all the tested codends in this study.

The dependency of towing speed and catch size for different catch sizes was established for three speeds and three catch sizes, see table 4.

Table 4 Model test values, and the converted full-scale values.

	Towing speed			Catch size, kg		
Model value	0,6 m/s	0,75 m/s	0,75 m/s	50	100	150
Simulating 1:2 scale	1.6 kts	2.1 kts	2,5 kts	400	800	1200
Simulating 1:3 scale	2.0 kts	2.5 kts	3.0 kts	1.350	2.700	4.050

Two codends were selected for this part:

- The standard 2 selvedges on the outside (ref. no. 2)
- T90 (ref. no. 6)

The recordings of the movements are given in figure 3.

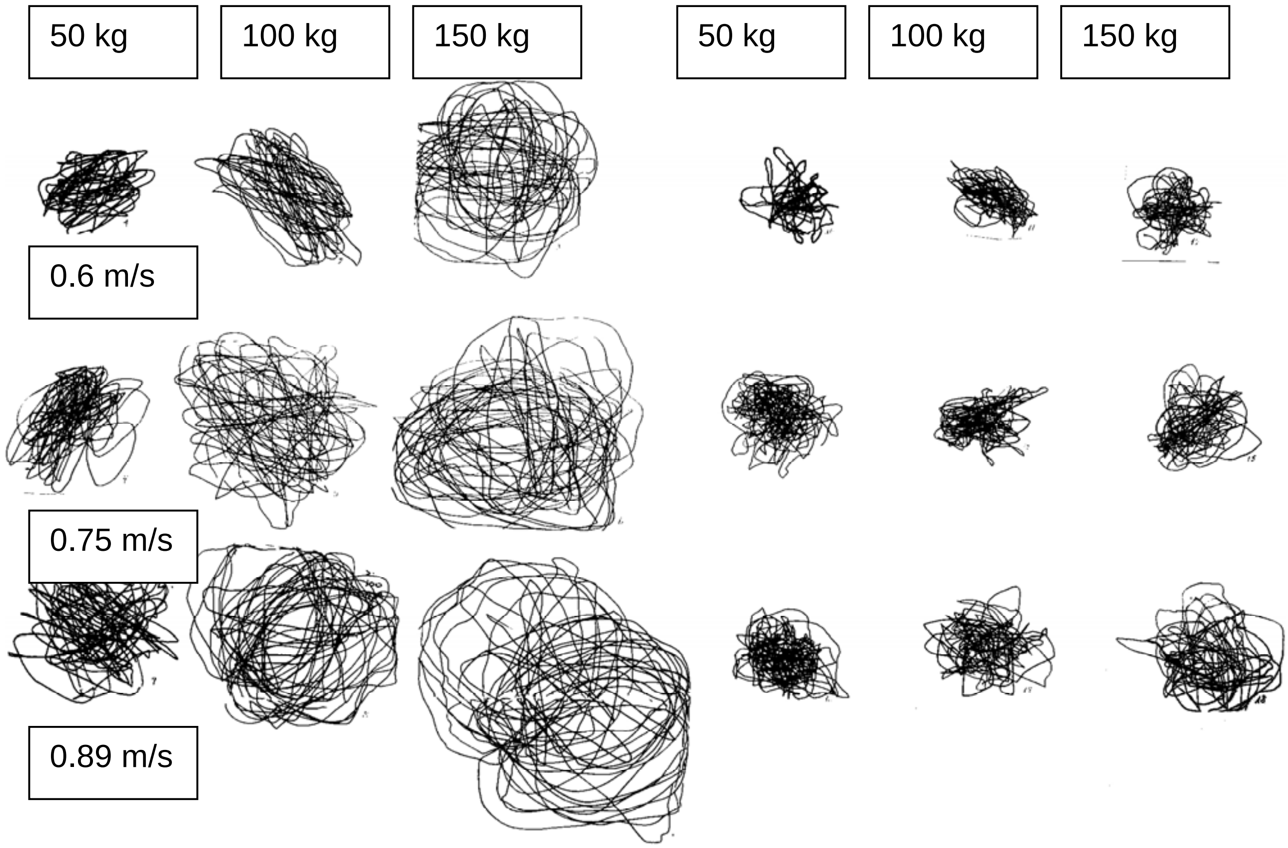


Figure 3 Recordings of codend movements as a function of speed (horizontal) and catch size (vertical).

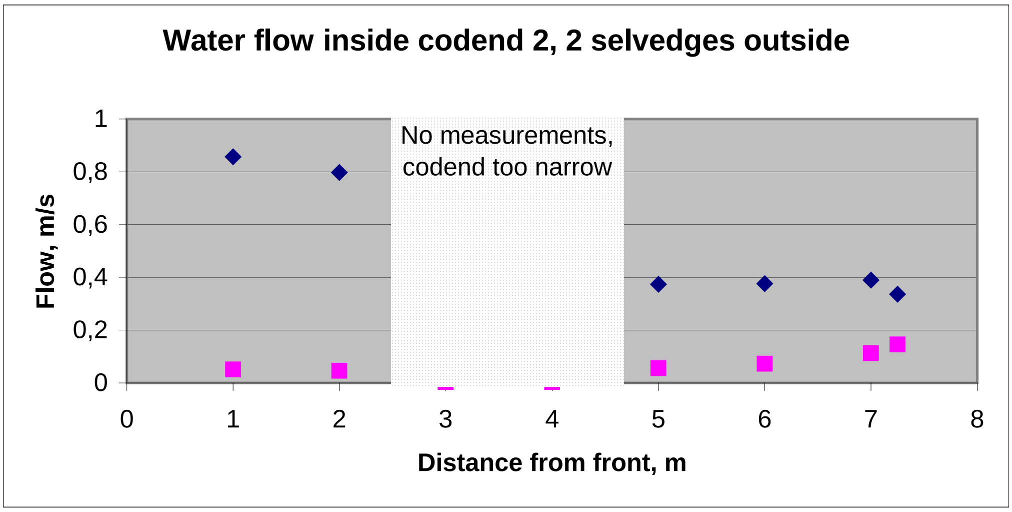
9 at left: Standard 2 selvedge outside, 9 at right: T90

There is a simple relationship between towing speed and movements. The same regards catch size and movements. The movements are however in all cases much smaller for the T90 codend.

Water flow

The water flow inside was measured in two codends: no. 2 (2 selvedges on the outside) and no. 6 (T90). Diagram 1 shows the results. The measurements were taken every meter down to the end and right in front of the catch at 7.25 m.

The water flow in the tank was set to 0.89 m/s and it can be seen that the flow in the standard 2 selvedge codend drops much more as we approach the rear end of the bag. 1000 measurements were taken over 100 seconds. The Standard Deviation is given for both sets and it gives an indication of the variation in flow and thereby the turbulence in the codend. The T90 codend has the smallest SD.



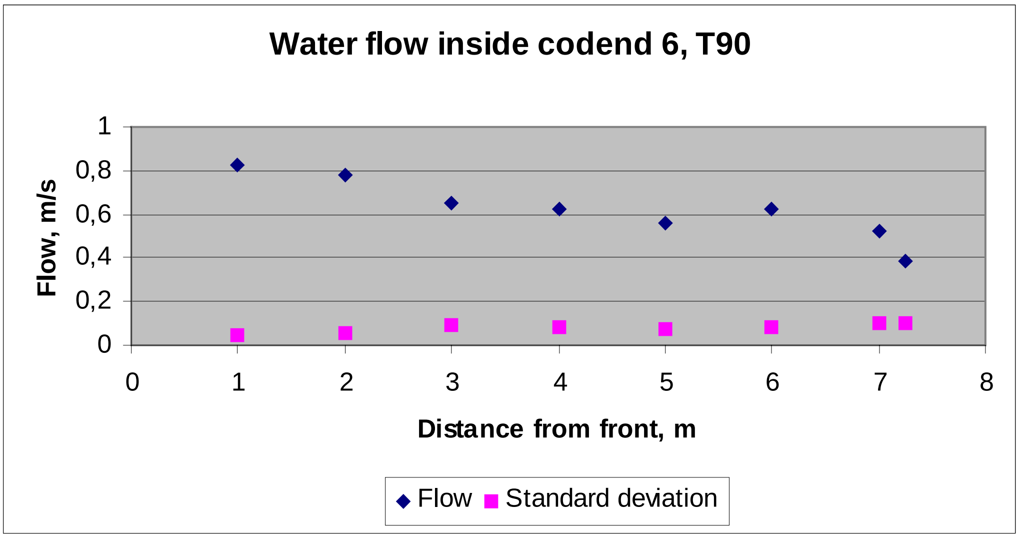


Diagram 1 Flow measurements in 2 codends

Resistance

The resistance was measured for some of the codends; see table 5. There is a tendency that the more volume a codend has, the more resistance it will have. However, pointing the codend with a netting cone reduces the resistance – in both the standard and the T90 codend.

Table 5 Resistance in selected model codends, "catch": 50 kg

Ref. no.	Codend construction	Resistance, kg
1	2 selvedges outside	27
2	2 selvedges inside	30
6	T90	40
9	2 selvedges outside, netting cone	22
10	T90 with netting cone	36
13	2 selvedges outside, 1/3 cone	30

The resistance is correlated to the catch size and the towing speed. Table 5 gives the results for 3 speeds and 3 different catch sizes. The dependency of the resistance to speed is following the general rules for drag, but it is interesting to note, that the drag as a function of catch size in the two codends reacts markedly different. The standard codend shows an increasing drag with larger catches, while the T90 codend shows only marginal or no increase.

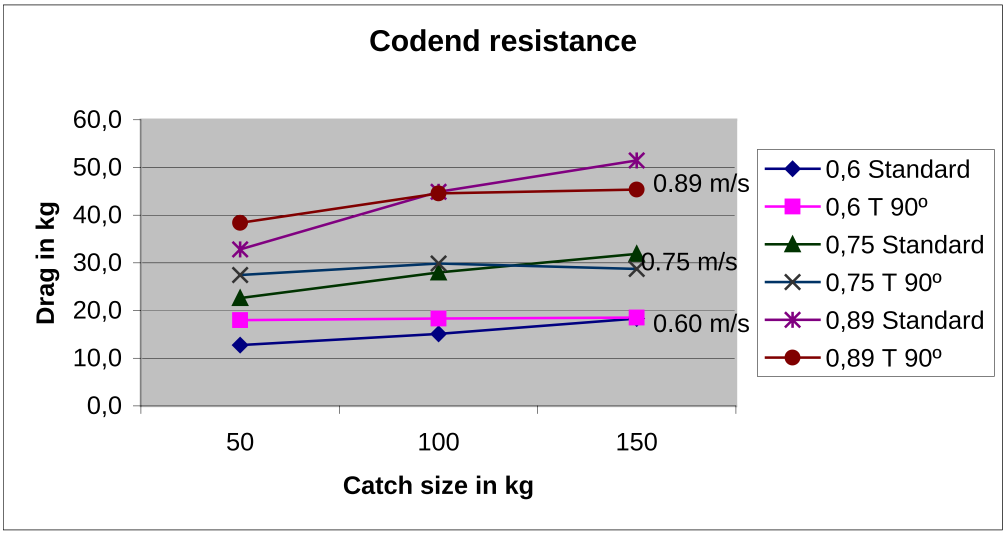


Diagram 2 The relation between catch size and drag in two different codends (no. 2 and 6) at 3 different towing speeds.

Discussion

The hypothesis of the project was that a codend with a large cross section area is more stable in the water than narrow codends. This seems to be confirmed by the flume tank measurements.

The testing of the codends was done with models, simulating 1:2 or 1:3 codends, where the "fish" were plastic bags. The results are therefore very close to reality. One important discrepancy is, that the fish were not alive, but the "behaviour" of the plastic bags in the model codend does not differ much from what can be seen on underwater observations of full-scale codends. Here it is often seen that the fish are so exhausted when they reach the codend, that float more or less involuntarily with the turbulent flow.

It can be argued that the reduced movement of codend is not a direct measurement of the ability to preserve fish quality. There is however strong evidence from numerous studies of the survival of fish after escape from the trawl, that the fish are more damaged from the netting in the trawl, and not so much – in itself – from the act of penetrating the netting and escapement (Main et al. 1990, Breen et al. 1997, Lehman et al. 1994, Lowry 1996). The damage is seen as pressure marks and other bruises to the flesh as well as damages to the skin. Moreover the skin damages are not seen around the girth of the fish but more in the head and tail regions. The explanation for these observations is that the fish have been pressed against the knots in the net and have been rubbing against the netting for some time.

The performance of the T90 codend in the flume tank has been very positive. The wide opening of the meshes gives a large increase to the circumference to the codend. The reason is partly due to the construction of the knot, partly to the bending of the four bars going out from each knot. The latter could be expected to lessen over time. However, there is so far very little evidence about the long-term effects of using this type of net. SINTEF have information from a few fishermen, which have been using T90 codends for up to one year. No exact measurements have been made on the mesh opening, but there have been no reports on any decreasing effect of turning the meshes around. It should be noted, that these fishermen have not changed to T90 sections in their trawls because of the quality preserving capabilities, but have been attracted by the prospect of an increased flow through the codend. The fishermen using T90 sections have mainly been using them in fisheries for small pelagic fish species, and have often shifted the rear section or sections in the belly and in some cases also the foremost section in the codend. They have all reported larger catches.

It is therefore expected that we will see a growing number of fishermen will try T90 sections in their trawls. Unfortunately little is so far known about the effects and possible side effects and the trials are therefore without scientific back up. It is possible, however, to evident that the main effect will when the netting is turned in the rear part of the belly and in the codend where the smallest meshes are found. In larger meshes the stiffness of the bars will be less efficient in “spreading” the knots from each other.

Because of the larger circumference of the T90 sections it has been the experience from the flume tank that the joining ratio between a T90 section and an ordinary section should be around 1:2 or 2:3. This depends very much on the type of net: material, twine thickness, construction of netting with single, double or triple twines etc.

By looking at the performance of the T90 net it is possible to deduce more properties than have been documented in this study. Here a summary of the deduced and the documented results of using T90 sections in trawls:

- Better quality of the catch: less turbulence
- Better selectivity: have been documented in the Baltic cod fishery (Moderhak 1997, 1999, 2000b, Zaucha et al. 1999)
- Better survival of escapees: when there is less damage to the catch, there will also be less incidental mortality among the escapees.
- Larger catches: the increased water flow pulls more fish towards the codend, sometime referred to as a reduced pressure wave in front of the codend.
- More large fish in the catch: this is often seen as a result of increasing the flow in a codend, for instance when using larger meshes or thinner twine.
- Stronger netting: has been documented at various laboratories and at netting manufacturers.

Conclusion

The project has revealed some basic information about how design and construction of codends can affect the performance of trawl codends under tow.

The aim of the project was to construct a codend with an improved ability to preserve the quality of fresh fish. The T90 codend seems to be a very good candidate to select for testing at sea. There is no reason to believe that the reaction will be much different in full scale and neither that it will react unexpectedly with larger catches or speeds.

The positive properties of netting turned 90º in relation to ordinary stretched netting are likely to tempt fishermen to use it, but it is also likely that the fisheries management will be interested in a widespread use. It is therefore very important that more experience is gained about the effect of using this type of net in various trawl fisheries and also about the effect on the T90 netting from various netting materials and netting constructions.

References

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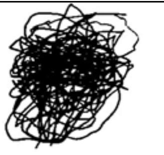
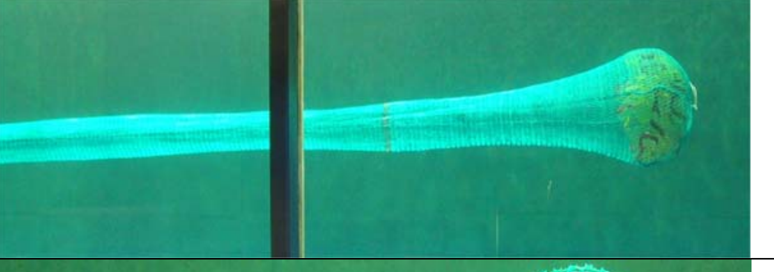
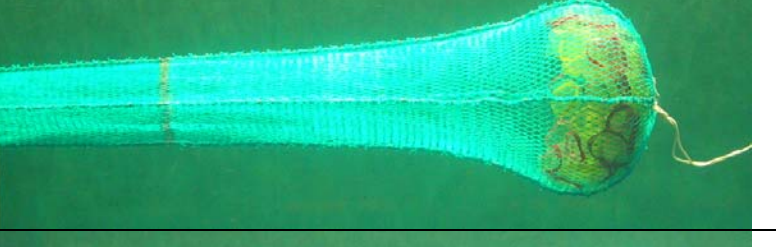
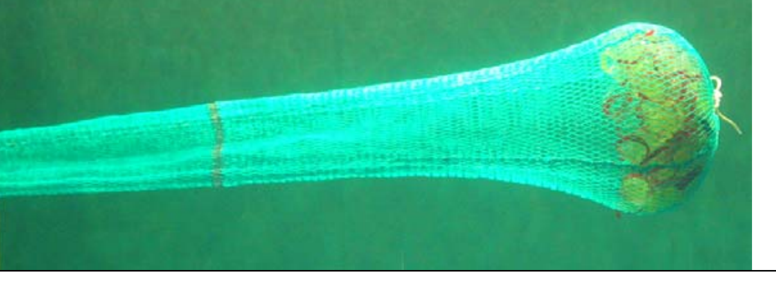
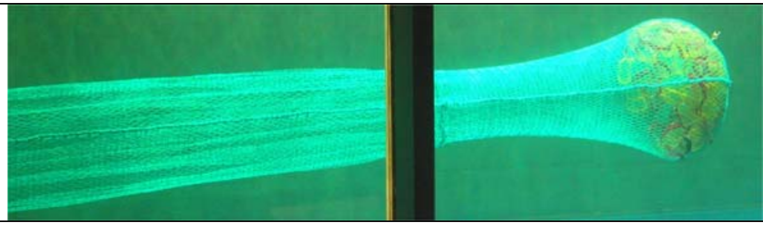
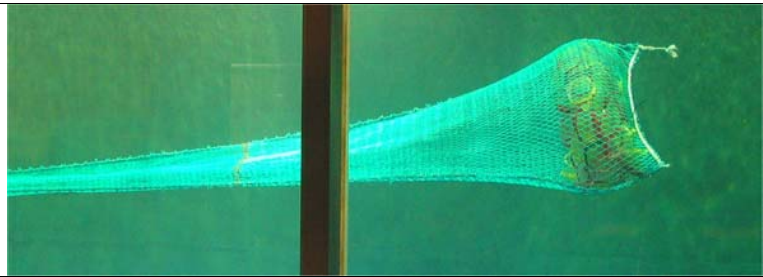
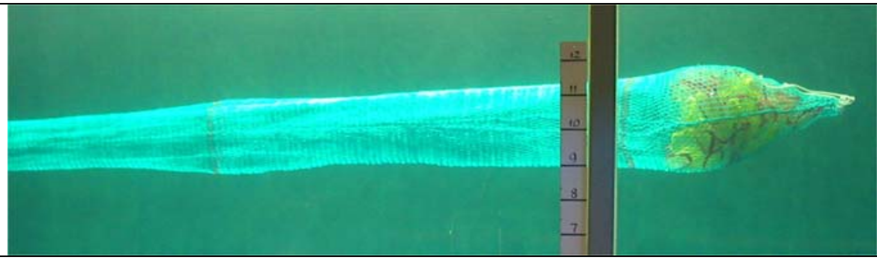
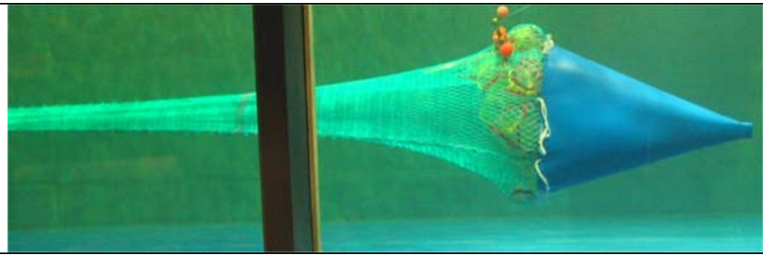
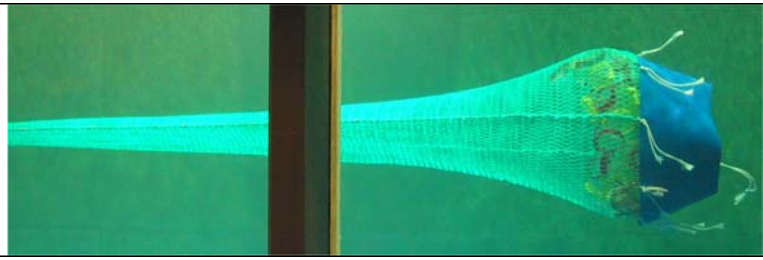
Appendix i - iv

Please note that the Flume Tank photos are not the same scale. However, the recordings from the video monitor at right are presented in the exactly same scale.

		Photo	Swings
Ref. no.	Overall construction	Please note that the photos are not exactly same scale	Same scaling
1	1 selvedge on the inside	n.a.	n.a
2	2 selvedges on the outside		
3	2 selvedges on the inside		
4	4 selvedges on the outside		n.a.
5	4 selvedges on the inside		n.a.

6	Ext.: T90 Lifting bag: ordinary		
	Effect of "Alaska knot"		
7	2 outer selvedges,		
8	Ext. and lifting bag T90		
	Effect of netting triangle		
9	2 inner selvedges,		
10	Extension and lifting bag T90	n.a.	

	Effect of canvas cone		
11	2 outer selvedges, full cone		
12	2 outer selvedges, 2/3 cone	n.a.	
13	2 outer selvedges, 1/3 cone		
	Effect of "liner"		
14	**Extension: T90** **Lifting bag: Ordinary net with small meshed liner**		

	Effect of canvas half sphere		
15	Extension: T90 Lifting bag: Ordinary netting Lifting bag: Ordinary net with small meshed liner