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Energy saving trawl in Mediterranean demersal fisheries

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ABSTRACT: This study aimed at the development of demersal trawl design, for the Mediterranean fisheries, with reduced fuel consumption. The new design include the use of a new high strength material and the use of larger meshes in net areas where no negative effect on the catching power is foreseen. It is essential that the new design combine the features of large headline height and good contact between the footrope and the seabed, with a low towing resistance. A typical trawl, commercially used in Italy, was selected as a basis for the development of the new design. This trawl became the reference to which the changes introduced in the new design were compared throughout the study. To reduce the netting area of the experimental trawl, a high strength Dyneema fibre was tested. The intention was to reduce the mesh twine diameter while keeping the netting strength constant. Dyneema was used in the wing section of the experimental trawl. Sea trials were made on a research vessel to measure the engineering performance of the trawls. During these tests a towed underwater camera was used to make a visual inspection of the trawls. The results from the sea trials show that it is possible to design trawls with up to 30% less fuel consumption and up to 40% more headline height, when larger mesh sizes, new high strength materials and reshaped wings are introduced. An inspection of the Dyneema netting after the commercial tests on the experimental trawl showed that the stability of the knots in this type of netting was not sufficient to keep the meshes rightly shaped. Further product development is necessary before such material could be commercially used in the Mediterranean fisheries.

1 INTRODUCTION

1.1 *Drag of the individual gear components*

A typical trawler spends a great part of fishing trip actually towing the fishing gear. During the towing, the drag of the vessel is low compared to the drag of the gear. Generally the fishing vessel drag is 15–20% of the gear drag (Fiorentini et al., 1981). The gear drag therefore has a large effect upon the overall fuel consumption of the vessels. The fuel costs for a typical trawler can be 50% of the total expenses on a fishing trip (Wileman, 1984).

Wileman (1984) made an analysis on how the individual components of the gear (trawl wire, doors, netting, floats and footrope gear) contribute to its overall drag. This analysis showed that, for a typical bottom trawler, nearly 60% of the total gear drag is contributed by the netting. Wileman and Hansen (1988) investigated in the flume tank the effect on the drag of models of a demersal trawl for the Danish industrial fishery, when reducing the netting area by larger meshes, thinner yarns or knotless netting in different parts of the trawl.

Tests showed that a drag reduction of 25% was achieved. Verhulst and Jochems (1993) made a series of tests where the polyamide ropes in the front part of a large Dutch pelagic trawl were replaced by ropes of high strength material (Dyneema SK 60). These tests showed that it was possible to obtain a towing speed about 10% higher for the same engine power. The mouth area was at the same time increased by 25%. Tests also showed, however, that the high stiffness of the new material could lead to broken meshes when the material was used in areas of the trawl with high loads.

In the current study, a traditional trawl type, which is commonly used in the commercial Mediterranean fishery, was selected as reference trawl and a new experimental trawl design has been developed. Sea trials have been made for both trawls.

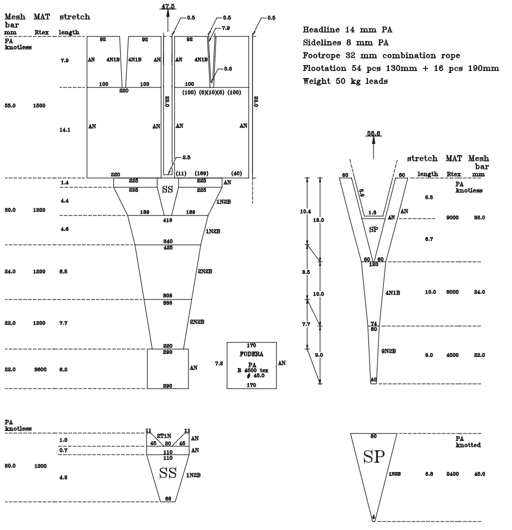

Figure 1. Design of the Mediterranean traditional trawl

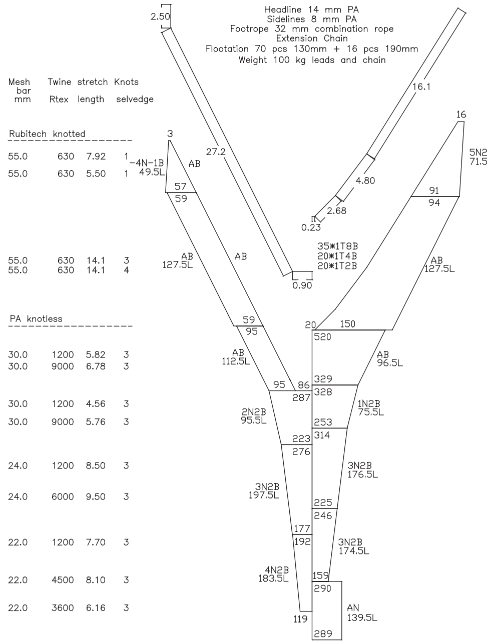

Figure 2. Design of the experimental trawl.

2 MATERIALS AND METHODS

2.1 *Trawl specifications*

A typical Mediterranean trawl projected for a vessel of 500 HP was selected. Both the traditional and experimental full-scale trawl designs are respectively shown in Figure 1. and Figure 2.

The features of the experimental trawl design are as follows:

(1) The knotless polyamide netting sections in the wings were replaced with panels cut from knotted Rubitech netting;

(2) the wings of the trawl have a totally new design: the mesh and yarn size are the same as for the traditional trawl. In the new wing sections, drop meshes are introduced along the headline side and the wing sections are split into upper and lower wing.

The newly introduced selvedge follows an all-bar (AB) cut. The cutting along the fishing line has been changed to an all-bar cut as well. This change in the design has been introduced to increase the headline length and hence to give a larger vertical opening. The design alteration resulted in a reduction of the netting area in the wing sections of approximately 7.5 % of the total netting area;

(3) the number of meshes in the upper and lower panel has been redistributed, compared to the traditional design. In the new design the width of the upper belly is only 1.14 times the width of the lower belly while the same ratio for the traditional trawl is 2.38. This change has been introduced to have wider lower wings in the trawl. The great amount of slack, which is usual in Mediterranean trawl design (named “Tartana”), has been incorporated in the new design as well. The redistribution of meshes from the upper to the lower panel will increase the netting area due to the difference in yarn diameter and the difference in length caused by the slack. The total netting area is increased by 7% compared to the traditional trawl. See Fiorentini et al. (2004) for the complete description of the gears.

2.2 *Engineering tests at sea*

Either the traditional or the experimental trawls were tested in the Adriatic Sea, at various depths, using the RV S. Lo Bianco. Polyvalent oval doors were used (1750 mm × 1050 mm). Warp lengths were paid out in relation to the bottom depth and during some hauls their length was altered in order to vary the spread of the net. In each haul, the net was towed on a fixed course and the vessel speed was varied in steps. In order to determine the effects of the sea current, at least two tows on reciprocal courses were made for each gear arrangement tested. The measured vessel parameters were vessel speed relative to the sea bed, warp loads, engine revolutions, shaft torque, shaft power and fuel consumption of the main vessel engine. The SCANMAR sensors were mounted on the trawls to measure the door spread, the upper wing-end spread and the bosom height above the sea bed. Wire loads were measured ahead of the four wing tips by underwater load cells inserted just in front of

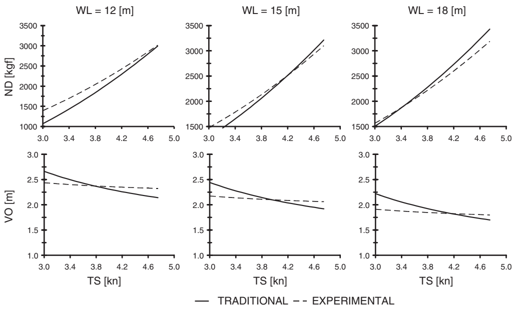

Figure 3. Comparison of the sea trials results obtained on the Mediterranean traditional and experimental trawls. ND[kgf]: Net Drag; VO[m]: Net Vertical Opening; TS[kn]: Towing Speed.

the wing-ends. Data were then processed by taking into consideration the effect of the sea currents on the towing speed.

The relationships of Vertical Opening (VO[m]) and Net Drag (ND[kgf]), according to testing conditions, with the other parameters (speed, current, horizontal net opening, etc.), were analyzed by means of General Linear Model (GLM). The analysis showed that, for all the parameters, a linear dependence upon speed was reasonably accurate, but a better approximation was achieved by correlating the net drag with the squared speed and the bosom height with the inverse of the speed. The second result of this analysis was that the other independent variable to be considered in the equation was the warp length. The use of further variables did not substantially improve the approximation of data.

All the statistical procedures were performed using the SPSS for Windows (version 10.05) software package.

3 RESULTS

3.1 *Engineering sea trials of trawls*

The General Linear Model (GLM) routine applied to the sea trials data provided suitable prediction mathematical models for both the experimental and the traditional trawls. The R-squares, ranging from 0.91 to 0.96, indicating a good fit to the data was achieved. The experimental data from the tests and the corresponding predicted curves are shown in Figure 3. Figure 4. shows the fuel consumption against the towing speed for both the traditional and experimental trawl.

After the first haul, it was observed that some meshes of the experimental trawl in the very end of the wing tip were broken in both sides of the upper panel. No attention was paid to this at first. During the succeeding haul in the reciprocal direction, a big difference (reduction) in headline height was measured compared to the first haul. During repeated tests in both directions it was never possible to reach the same height as in the first haul. A possible explanation for the breakage of the meshes and the resulting change in the performance of the trawl is the combination of the design and the small elasticity of the Rubitech material. A visual inspection of the wings after the commercial trials gave a possible explanation to the problem. In fact, a change in the shape of the meshes was obvious and it indicates that the stability of the knots was not sufficient to carry the load in the wing sections of the trawl, where the two bars in the mesh have different load. Displacements of the knots of more than 20% were observed in the heaviest loaded areas of the wings. These displacements have of course resulted in a change in the distribution of the load finally causing a restriction of the vertical opening of the trawl. One method for reduction of the tension in the wing end meshes was to redesign the upper wings so that more meshes were left at the very wing tip to carry the load. After the alteration of the wing tip, the experimental trawl was again tested at sea. The results of the sea trials, in fact there was no significant difference at sea between the two trawls in their vertical opening. Sea trials showed that the experimental trawl had a drag higher than the traditional trawl only at low net spread, while, at high net spread, the experimental trawl had less drag than the traditional one.

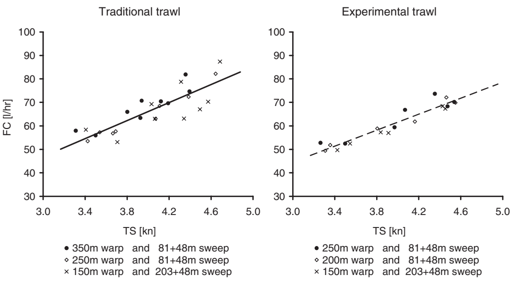

Figure 4. Fuel Consumption (FC[1/hr]) against Towing speed (TS[kn]) for the Mediterranean traditional and experimental trawls.

The best trawl performance improvements of the experimental trawl compared to the traditional one were recorded at medium net spread (15 m), with both a reduction in drag and an increase in headline height. At high net spread the reduction in drag (5%) is partially compensated by a reduction (16%) of headline height at low speed. On the other hand, at low net spread, the increase in headline height (7–24%) is partially compensated by an increase in drag, which is 15% at low speed.

4 CONCLUSION

The material tests showed that the knotted Rubitech netting, as it was produced, was suitable for use in fishing gear. The yarn thickness of the final netting was appropriate to obtain substantial fuel savings in the trawl. Therefore the knotted Rubitech netting showed good properties to be able to replace the polyamide in the Mediterranean trawls. The biggest problem with the new material was the knot stability. With the exception of the knot stability, the overall condition of the high strength Rubitech material was good after the completion of the sea trials: a visual inspection showed no abrasion. The difference in trawl behaviour can be explained by the difference in design between the traditional and the experimental trawls. In the wings of the traditional trawls a large number of meshes are carrying the load due to the drag of the aft part of the trawl. The reshaping of the wings in the experimental trawl has reduced the number of meshes in the wings. So, fewer mesh bars have to carry the load. The elasticity of the full scale material will therefore have a much larger influence on the shape of the experimental trawl than for the traditional trawl. The observed displacement of the knots in the stiff Rubitech material used in the wing section of the experimental trawl together with the high headline heights measured in the very first haul performed after the new material was incorporated also indicate that the differences between model and full scale results are caused by differences in elasticity between model and full scale material. There is a remarkable difference in the behaviour of the experimental trawl compared to the traditional trawl.

The drag of the traditional trawl increases when the wing end spread increases, while the drag of the experimental trawl decreases for increasing net spread at constant towing speeds. An increase in spread has a greater influence on the headline heights of the experimental trawl compared to the traditional trawl. Therefore an increase in net spread will result in a reduced mouth area for the experimental trawl, while it will give an increase in mouth area of the traditional trawl. The engineering tests at sea showed good results for the experimental trawl. Sea trials showed certainly an improvement compared to the old typical trawl (Fiorentini et al., 1991; 1992; Fiorentini and Cosimi, 1987). The costs to realize the experimental trawl with traditional material are very limited. The cutting and the hanging of the wings are a little bit more complicated than that of the traditional trawl and this will require more working time. Also, the use of the new materials is interesting for the experimental trawl. A financial analysis of the possible benefits, deriving from the use of the experimental trawl in place of the traditional one, was made. The result is that the payback time is of only a few months. The assumption made in these assessments is that the catching power is equal for all the trawls, but the lower drag of the experimental trawls would produce a fuel consumption saving. Assuming that the fuel spent in trawling activities is 80% of the total and that the fuel costs can be 50% of the total expenses on a fishing trip (Wileman, 1984), the savings from the use of the experimental trawl incorporating the Rubitech is about 3% of the total operating costs. Finally, to evaluate the importance of fuel saving, it must be considered that oil is not a renewable resource and that the Community shows a large deficit in this sector.

4.1 *Future works*

The number of fishing tests done during the present work was limited. Other commercial tests would be necessary to draw definitive conclusions.

The present state of development of the experimental trawl is considered satisfactory. In particular the benefits deriving from their use are substantial, even if a setting up is necessary for the different fishing grounds, but this work would be done by the fishermen through their daily use.

Future work can be foreseen in particular for the experimental trawl. The knot instability of the high strength material prevented the trawl to reach the performance expected. The Danish company which produced the material claims to have solved the problem. The intention is to test this new material in place of the old one in order to increment the benefits recorded.

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