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An experimental/numerical study of the catch weight influence on trawl behavior

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ABSTRACT

Measurements at sea during fishing trials on bottom trawl have revealed that the geometry of the trawl is affected by the catch. A series of 37 hauls of around 3 h were carried out during the French EFFICHALUT project. The aim of this project was to carry out improvements on the fishing gear in order to reduce energy consumption. For this project, numerous sensors were used: for bridle tension, door spread, vertical opening, and door attitude. The measurements show quite clearly that the door spread decreases and the bridle tension increases during most of the hauls. The door spread decreased by 1.35 m/h, with a standard deviation of 1.98 m/h while the top bridle tension increased by 47 kg/h, with a standard deviation of 59 kg/h. The mean catch per haul was around 1.48 t. The modeling of the trawl gear and the catch with a FEM model helps to explain the variation in the door spread and the bridle tension: the numerical model shows a mean decrease of 1.06 m/h for the door spread and a mean increase of 76.0 kg/h for the top bridle tension. The modeling were developed by the first author in previous studies.

1. Introduction

During the last couple of years, numerous studies on fuel efficiency of fishing gear have been carried out following the large increase in energy cost. One of them, the EFFICHALUT project (Priour, 2012), was dedicated to enhance the energy efficiency of the bottom trawl. During this project, numerous measurements at sea on the bottom trawl were carried out and exploited, but some findings have not been described because they were outside the scope of the project. In the present paper, we propose to analyze one of these findings, which is about the effect of catch on gear geometry behavior.

Trawl performance is investigated using flume tank tests (Ward and Ferro, 1993; Ferro et al., 1996), full scale tests at sea (Sala et al., 2011), analytical modeling (Park, 2007), or numerical model (Lee et al., 2005; Tsukrov et al., 2003; Priour, 2003, 2013a). These investigations take into account the design of the gear, the water speed, and the bottom contact, but there are few studies on catch effect in the bibliography; only two seem relevant. In the first study on this subject, which was based on exhaustive flume tank experiments, O'Neill et al. (2005) concluded that the towing speed and the maximum frontal area of the codend were the predominant components of the codend drag. The second study dealt with the development of a numerical-statistical model of the catch shape and volume inside the codend, also based on flume tank tests (Priour and Herrmann, 2005).

However, these studies have their limitations (as mentioned in Priour and Herrmann, 2005): (i) they were based on scaled flume tank experiments; (ii) the fish catch was reproduced as water bags, and it was not physically possible to reproduce the same ratio between the catch volume and the mean volume of a single fish used in the fishing process at sea; and (iii) only the codend was tested in the flume tank, instead of the whole trawl.

Therefore, the aim of the present work is to analyze the effect of catch weight on trawl behavior by using the real measurements at sea from the EFFICHALUT project. Moreover, these measurements are compared with the solution obtained using a numerical model. It is worth noting that this study on catch effect, although less exhaustive, was presented previously by one of the authors in the DEMAT 2013 conference (Priour, 2013b).

The remainder of the paper is organized as follows: Section 2 describes the trawl and methodology followed for the experimental measurements. Section 3 describes the numerical model of the whole trawl, that is, the net, the wires, the doors, contact with the seabed, and the catch. Section 4 shows the results of the experimental measurements and the comparison with the numerical model. Finally, Section 5 provides the discussion and the conclusions.

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2. Methodology for experimental measurements

2.1. Description of the trawl gear

The trawl used in the experiments was a bottom trawl. The plans were provided by the fisherman and are shown in Fig. 1. The doors, from the Morgere company (Oval Foil model), were 2.9×1.85 m wide and weighed 1.4 t. The rigging is defined in Fig. 2. The warp length was around three times the water depth, 150 m for the first week at sea and 60 m for the second one. The main fish species were mackerel, whiting, gurnet, gurnard, horse mackerel, and sea bass. The fisherman operated the trawl at constant engine power (107 l/h of fuel).

2.2. Measurements at sea

Tests at sea were carried out for two weeks. The depth was around 50 m during the first week and 20 m for the second. The trawl was equipped with 6 tension sensors: on each bottom bridle, top bridle, and warp (Fig. 3). The tension values were recorded using NKE SF sensors (range, 5 t; accuracy, 25 kg; and resolution, 2.2 kg). The door depth, spread, and attitude (heel and trim) were also recorded. The sensors used were NKE S3AP for door attitude and SCANMAR sensor for the door spread. The water speed on the head rope and the ground speed, as well as the vertical opening of the mouth of the trawl, were measured. The water speed and the vertical opening were measured with SCANMAR sensors fastened to the headline of the trawl. The ground speed was measured with a GPS on the boat.

The duration of the haul was more than 1.5 h; otherwise, the haul was removed from the set of hauls, such as the event at 677 h in Fig. 4.

Not all the measurements were valid due to dysfunctioning sensors or loss of acoustic link between the acoustic sensors and the boat. A clean-up of the measurements was necessary: only the values for water speed between 1 and 8 m/s were kept; otherwise, the loss of acoustic link with the sensor was suspected. For the same reason, the measurement of the door spread was kept if it was within the range defined by the mean values of the door spread of the haul plus or minus 15 m. Similarly, the bridle tension (top and bottom) were kept if they were between 200 and 2000 kg; otherwise, the measurements did not seem reasonable.

Unfortunately, the catch of each haul was not recorded; only a rough evaluation of the total catch was made by the fisherman. The mean catch per haul was 1.48 ts.

3. Modeling the gear

3.1. Finite element model

The modeling is founded on the finite element method (FEM) model of the net based on a triangular element (Priour, 1999, 2013a). The FEM model takes into account the inner twine tension, the drag force on the net due to the current, the pressure created by the fish catch in the codend, the floatability and weight of the net, the contact on the bottom, and the contact between knots of the netting, which limits the closure of meshes.

The FEM model is able to describe all the net and cables; this means that for a trawl, the codend, the wings, the headline, and also the rigging up to the boat are taken into account.

The net is modeled into triangular elements, whereas the cables, warps, bridles, and bars are modeled in linear elements (bars).

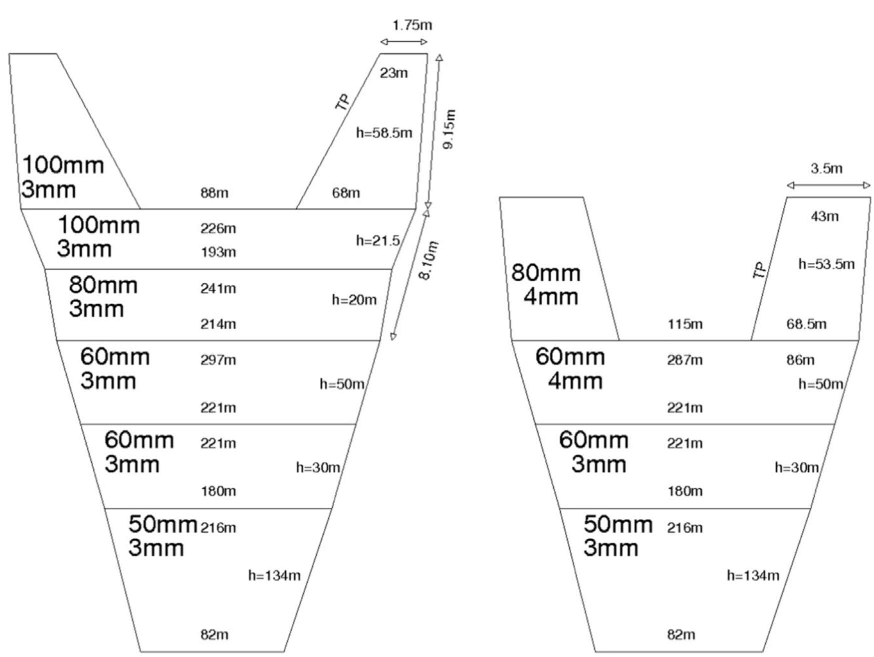

Fig. 1. Design of the trawl. The mesh size and twine diameter are on the left. The panels size is noted in mesh numbers and the cables in meters.

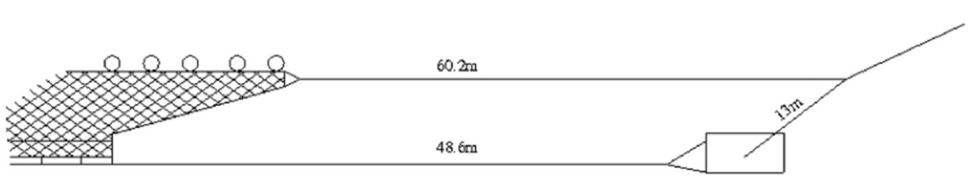

Fig. 2. Design of the rigging. The top bridle is fixed to the warp.