Abstract—The trawling fishing system is nowadays the most important and more used among all the caught systems in the fishing industry. Its most significant feature relies on the capability of capturing very different fish species. The modern technology seems to be the way to reach major improvements in such an environment, where there’s not enough data available for research. When looking for new solutions, simulation and optimization of new models will surely reduce manufacturing costs.

Keywords—Fishing, Optimization, Trawl geometry, Trawl net, Type of cut.

I. INTRODUCTION

In this paper a novel stadium design of fishing nets oriented application is presented, related to the types of cut of the net to allow its subsequent manufacturing.

With this innovative application it will be possible to manage a large number of types of cut. Among these types of cut, the usual cuts in the construction of nets are included, as well as combinations of them [1].

The type of cut for fishing nets is a determining factor in how the net will work in the sea, since this factor is directly related to the width and length of the fishing net as well as to the type of fish to capture and even with the type of trawling system [2], [3].

The characteristics of the target to be captured, the distribution type and the form of fish concentrations, and the nature of their migration determine fundamentally the type of trawling system and the type of construction of the fishing net [4].

For example, in the case of pelagic species, which inhabit most of the time in layers of half water, we must use the half-water trawling system. While if the species is located on the seabed or near it, the bottom trawling or semi-pelagic system is chosen.

Regarding the type of construction of the net, it is especially determined on the basis of concentrations of species to capture. That is, each species moves along the sea in a particular way, forming different shapes for shoals [5], [6], [7], [8].

The result of this analysis lets the designer choose a net more or less elongated in the vertical or horizontal plane.

II. STATE OF THE ART

So far the basis geometry has been dealt with, as a simplification way for application in formulas, as dependent of the coefficients of vertical and horizontal opening of the grid [9].

Another approach to the problem might involve taking into account each netting individually, as shown in the next figure.

![Fig. 1. Computer aided software for fishing nets design.](image)

The panel, when we understand it as a constituent of the nettings, which make up the structure of the fishing net, has been modelled on other occasions in a very simplified way, as shown in the following figures.
The extension of the model based on individual elements, saving neighbourly relations among the nodes once they are grouped, covers the definition of all types of panels with or without lateral different cuts [10], [11], [12].

III. GEOMETRY

For all the calculations that are going to develop below, some basic relationships have been taken into account to be fulfilled in the structure of basic mesh (structure that will be repeated in the geometric shape determined by the cuts in different parts of all the nettings).

That structure, as you can be see in Figure 4, consists of 4 sides and 4 vertexes (concurring in turn each of these vertexes with the coordinates of the 4 nodes located at the intersections of these sides).

The length of the sides (longitud) can be obtained in several ways:

Height of the mesh 2H:

\[ H = A \cdot \cos(\beta) = A \cdot \sin(\alpha) \]  
(1)

Width of the mesh 2W:

\[ W = A \cdot \cos(\alpha) = A \cdot \sin(\beta) \]  
(2)

By default the values of 60º and 30º for angles alpha and beta respectively are considered as initial conditions, at least for the static case in 2 dimensions (this could change within the configuration of the application).

IV. MATHEMATICAL DEVELOPMENT FOR THE TYPE OF CUT X P Y M

The figure below shows the outlines of the basic forms related to the types of cuts:

Fig. 4. Basic forms for the construction of the various cuts.
The mathematical expressions related to the cuts of the type $XpYm$, depending on the angle $\alpha$, as in (3) and (4):

**Calculation angle $\theta$ - (2p2m):**

$$\cos(\theta) = \frac{\alpha \cdot \cos(\alpha)}{\sqrt{\alpha^2 \cdot \cos^2(\alpha) + (2 + 4)^2 \cdot \alpha^2 \cdot \sin^2(\alpha)}}$$  (3)

**Calculation angle $\gamma$ - (2p2m):**

$$\cos(\gamma) = \frac{(2 + 4) \cdot \alpha \cdot \sin(\alpha)}{\sqrt{\alpha^2 \cdot \cos^2(\alpha) + (2 + 4)^2 \cdot \alpha^2 \cdot \sin^2(\alpha)}}$$  (4)

Expressions depending on $\beta$:

**Calculation angle $\theta$ - (2p2m):**

$$\cos(\theta) = \frac{\alpha \cdot \sin(\beta)}{\sqrt{\alpha^2 \cdot \sin^2(\beta) + (2 + 4)^2 \cdot \alpha^2 \cdot \cos^2(\beta)}}$$  (5)

**Calculation angle $\gamma$ - (2p2m):**

$$\cos(\gamma) = \frac{(2 + 4) \cdot \alpha \cdot \cos(\beta)}{\sqrt{\alpha^2 \cdot \sin^2(\beta) + (2 + 4)^2 \cdot \alpha^2 \cdot \cos^2(\beta)}}$$  (6)

Fig. 5. Expressions and geometry of the type of cut 2p2m.
Fig. 6. A application for conversion of types of cuts [Matlab].

Fig. 7. Dialogue of the application for conversion.
corresponding formula), and later use an implementation of sorting algorithm QuickSort directed to the structures of type of cut that have been mentioned, and perform a growing order on the basis of this angle. The list at the bottom of the dialogue is filled on the basis of this list of data pairs (type of cut-angle) once it has ordered.

![Fig. 8. Complete list of conversions.](image)

With the array of pairs of data ordered, application will do any request to resolve the most approximate type of cut through the angle, conducting a search within the array, to find, within the available list, the angle that offers a lower difference with the angle inserted by the user.

Regardless of which of the two options for conversion is chosen (conversion angle to type of cut or type of cut to angle), the system represents at the right side of the dialogue the outcome of the application. The figure shows the representation of the type of cut 1p1m on the right side of the application.

For the representation, we use the geometry of the panel and the type of cut selected, we make a series of triangulations of position on the basis of known coordinates and of a basic grid with structure Lattice (resulting of normalizing the grid of generation of coordinates based on standard dimensions of the basic mesh of the used panel). And with all these data the system decides whether it represents or not the corresponding line between the source node and the destination node in question.

Finally, it is possible to run the application from the command console. The options are similar in regard to the possibility of conversion, except for the fact that it is possible to get a complete list of available conversions in the initialization array.

Anyway, the application supplies help. The result is obtained in the standard output, with the possibility of using pipes to redirect to a file.

The following table shows some of the types of cut most widely used in manufacturing, along with its conversion to associated equivalent attack angle and step coefficient. Data have been generated by applying Types of Cut (for Matlab environment).

<table>
<thead>
<tr>
<th>TYPE OF CUT</th>
<th>ANGLE [º]</th>
<th>STEP COEFFICIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>tm</td>
<td>0º</td>
<td>0</td>
</tr>
<tr>
<td>2p11m</td>
<td>2.7545º</td>
<td>0.083333</td>
</tr>
<tr>
<td>2p7m</td>
<td>4.1278º</td>
<td>0.125</td>
</tr>
<tr>
<td>2p5m</td>
<td>5.4964º</td>
<td>0.16667</td>
</tr>
<tr>
<td>2p3m</td>
<td>8.2132º</td>
<td>0.25</td>
</tr>
<tr>
<td>1p1m</td>
<td>10.8934º</td>
<td>0.3333</td>
</tr>
<tr>
<td>2p1m</td>
<td>16.1021º</td>
<td>0.5</td>
</tr>
<tr>
<td>3p1m</td>
<td>19.10º</td>
<td>0.6</td>
</tr>
<tr>
<td>4p1m</td>
<td>21.0517º</td>
<td>0.66667</td>
</tr>
<tr>
<td>5p1m</td>
<td>22.4109º</td>
<td>0.71429</td>
</tr>
<tr>
<td>tp</td>
<td>30º</td>
<td>1</td>
</tr>
<tr>
<td>4p1mf</td>
<td>40.8934º</td>
<td>1.5</td>
</tr>
<tr>
<td>2p1mf</td>
<td>49.1066º</td>
<td>2</td>
</tr>
<tr>
<td>1p1mf</td>
<td>59.99º/60º</td>
<td>3</td>
</tr>
<tr>
<td>tmf</td>
<td>89.99º/∞</td>
<td>1000000~∞~(x)</td>
</tr>
</tbody>
</table>

VI. Conclusion

The mathematical developments of the types of cut used in the nettings used in the fishing industry allow generalize calculating profiles so that it is possible to know the contours of a panel according to the openness that the configuration of its basic mesh presents. This knowledge provides significant benefits for the modelling structures that allow deal with the simulation of the hydrodynamic behaviour of fishing nets.

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Javier Bilbao obtained the degree in Electrical Engineering from University of the Basque Country, Spain, in 1991. At present he is Ph.D. in Applied Mathematics and professor at the department of Applied Mathematics of that university.

He has been General Chairman of some conferences of WSEAS organization. Current and previous research interests are: Distribution, overhead electrical lines compensation, Optimization of series capacitor batteries, Modelization of a leakage flux transformer, Losses in the electric distribution Networks, Artificial Neural Networks, Modelization of fishing trawls, E-learning, Noise of electrical aerogenerators, Light pollution, Health risk of radiofrequencies.

Prof. Bilbao is the General Chairman of the International Conferences on Engineering and Mathematics (ENMA) and member of the committees of the Technical and Physical Problems of Power Engineering (TPE) International Conferences.

Eugenio Bravo obtained the degree in Electrical Engineering from University of the Basque Country, Spain, in 1991. At present he is Ph.D. in Applied Mathematics and professor at the department of Applied Mathematics of that university.

Olatz García obtained the degree in Mathematics from University of the Basque Country, Spain, in 1989. At present she is Ph.D. in Applied Mathematics and professor at the department of Applied Mathematics of that university.

Concepción Varela obtained the degree in Mathematics from UNED, Spain, in 1986. At present she is Ph.D. in Economics and Statistics and professor at the department of Applied Mathematics of the University of the Basque Country.

Miguel Rodríguez obtained the degree in Physics from University of Navarra, Spain, in 1978. At present he is Ph.D. in Electronic Engineering and professor at the department of Applied Mathematics of the University of the Basque Country.

Alexander Odriozola obtained the degree in Telecommunications Engineering from University of the Basque Country, Spain, in 2007. He is now in Ibermática, consulting for ICT.