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# Some problems of water flow through trawl codend

by
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## 1. Abstract.

The paper presents calculations of water flow velocity through the codend under the assumption that the flow is uniform and equal on its entire surface. The calculations were made for different ratios of codend length to its diameter, mesh bar length to mesh bar diameter, and for various mesh opening coefficients. The results obtained were analysed with regard to the impact of flow velocity on hydrodynamic forces opening the codend. These forces, different for different codend constructions, have great impact on selection properties. The greater velocity of water outflow is effecting the wider opening of the codend meshes and a greater probability of undersized – juvenile fish escaping.

An idea of a new setup of meshes in the codend, changing the effect of operation of longitudinal forces (hydromechanical drag forces) was presented. Closing forces become mesh opening forces, which should ensure greater mesh opening coefficient and better selectivity of the codend of the trawl.


## 2. Introduction.

The construction of a trawl codend is not neutral for hydrodynamical and mechanical phenomena taking place inside it and influencing the degree of opening of the net meshes. Specific possibilities of allowing the passage of fish or other marine organisms present in a given area are connected with the opening of the codend meshes, i.e., with the selectivity of the web used for codend construction.

The degree of opening of the codend meshes depends on a system of forces acting upon them. This mainly concerns hydrodynamic forces, generated by the conditions of water flow into the codend.

An algorithm (model) was elaborated to imitate the behaviour of the codend in water. This imitation consists in a change of dimensions (diameter and length of the codend) as a result of a change of the mesh opening coefficient. The model is based on the assumption that the entire volume of water flowing into the codend must flow out of it (low of continuity). The model for the calculation of water flow through the codend is based on the following assumptions:

- the trawl codend has the shape of a rigid, simple circular cylinder,
- the trawl codend is made up of one layer of the net material,
- diameter of the knot (dw) is such that $(dw/d)^2 = 10$; d is the diameter of the twine (Krauze 1979, Dickson 1980),
- a fixed state of water flow through the codend is being considered,
- water flow is uniform on the entire side surface of the codend,
- there is no flow through the closing wall of the codend; the entire amount of

water flows out through the side surface (Bielov 1990),
- the amount of water flowing into the codend is such that there is no flow of water from outside the codend.

The paper presents calculations of normal velocity of water outflow from the codend made of a knotted net. In order to present the results of calculations with lucidity, it was decided to present them in a function of of non-dimensional coefficients characterizing both the net used for construction and proportions of trawl codend dimensions. The net is well characterized by coefficient **l/d** (length of mesh bar/diameter of mesh bar), and the proportions of the codend working in the water (elongation) coefficients **no/n** (number of meshes in codend circumference/number of meshes of codend length) and **U1** (coefficient of horizontal opening of meshes). These three magnitudes characterize the construction and shape of the codend, as a simple circular cylinder. Since these are non-dimensional coefficients, conclusions resulting from the patterns of the calculated velocity in a function **l/d, no/n, U1** are universal for a group of similar codends (according to the laws of similarity). These coefficients are independent of each other, i.e., do not influence each other's value.

Among the parameters given only **l/d** and **no/n** are magnitudes, which a trawl designer may shape as he wishes. The coefficient of horizontal mesh opening **U1** is a parameter of the work of the web and is difficult to determine through theoretical calculations. It is shaped, for a concrete construction, by the system of hydrodynamic forces, gravity and elasticity of the web, acting upon the web of the codend.

### 3. Impact of mesh opening coefficient U1 on normal velocity.

Figure 1 presents a graph of normal velocity of water outflow from the codend **Vn** in a function of the mesh opening coefficient **U1**, for a trawler herring codend with **l/d** = 14 and **no/n** = 0.68.

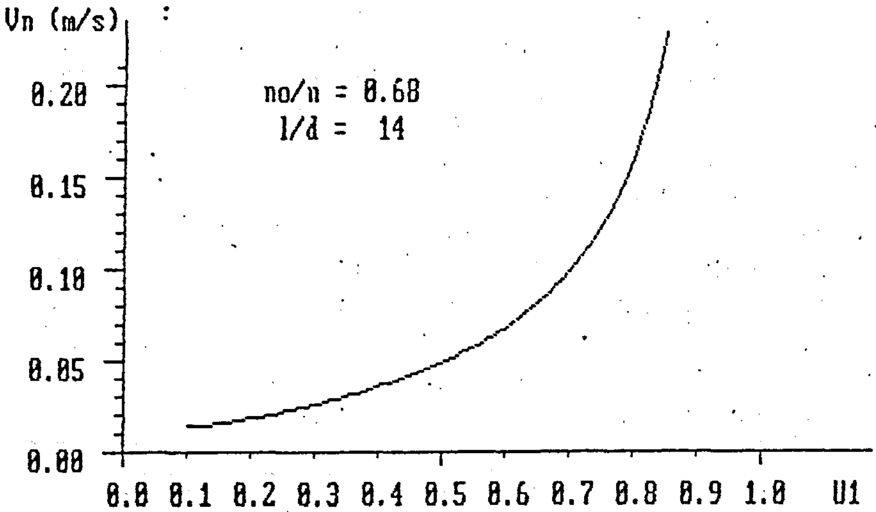


Fig. 1. Relationship between normal velocity of water outflow from the codend and mesh opening coefficient.

The velocity of water outflowing from the belly into the codend was assumed at 1 m/s. It appears from the graph that the mesh opening coefficient has a great impact on the velocity of water outflow from the codend. For coefficient values greater than 0.5 (for **no/n** = 0.68), the velocity increase is considerable. This is connected with an increase in the diameter of the codend inlet and the simultaneous decrease in its length, accompanying the increase in the mesh opening coefficient. The velocities occurring in the flow are shaped by hydrodynamic forces acting upon the web. The mesh opening is explicitly determined by forces acting upon the mesh. The greater opening of the meshes is a result of greater opening forces.

**4. Impact of codend elongation no/n on normal velocity.**

An analysis of changes in normal velocity, accompanying codend elongation, may be made using the results of calculations of normal velocity in a function of coefficient **no/n** (codend elongation). An example of the results of calculations for a herring codend are presented in Figure 2. Normal velocity of outflow increases

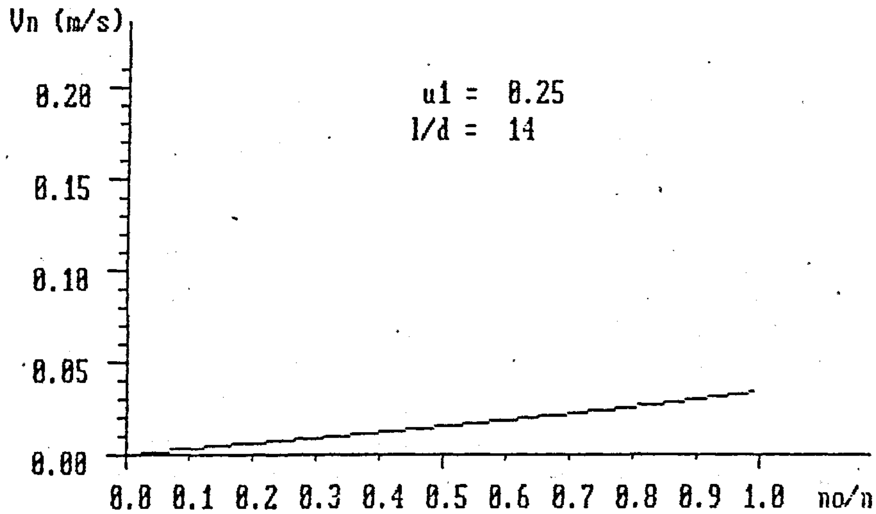


Fig. 2. Relationship between normal velocity of water outflow from the codend and codend elongation.

with an increase in coefficient **no/n**. This coefficient may be altered by changing the codend length or circumference. Decreasing the number of meshes of the codend length **n** increases the value of coefficient **no/n**, thus increasing normal velocity of water flow through the side wall of the codend. The pattern of function **Vn = f(no/n)** depends to a large degree on the mesh opening coefficient **U1** (see Fig. 1) and the ratio of the mesh bar length to its diameter (**l/d**), especially for small values of the coefficient of mesh bar elongation (see Fig. 3).

**5. Impact of mesh elongation coefficient l/d on normal velocity.**

Figure 3 presents an example of the pattern of normal speed of water outflow in a function of mesh bar elongation – **Vn = f(l/d)**. The analysis of the graph makes it possible to determine that the velocity of water outflow from the codend decreases with an increase in mesh bar elongation. For the codend analysed here, for a range up to **l/d** = 9, this decrease is quite large and then slows down. It appears from this that inceasing the length of the mesh bar (while maintaining the same diameter) results in a decrease in normal velocity of water outflow and thus a decrease in the forces and the mesh opening coefficient. Correct construction of trawl codends should consist in such a decrease of the ratio **l/d** of the mesh, so that to attain the range of great decreases of velocity (here the reduction of the

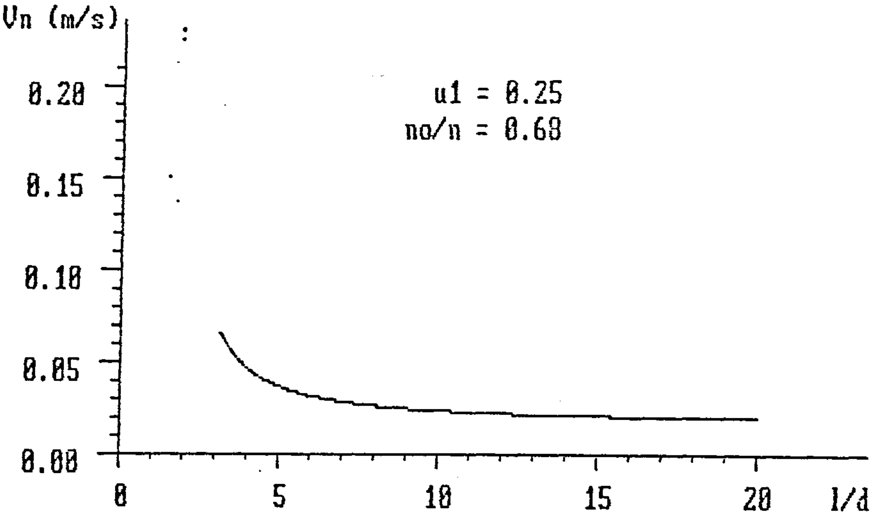


Fig. 3. Relationship between normal velocity of water outflow from the codend and mesh elongation coefficient.

the ratio **l/d** causes an increase in normal velocity of water outflow from the codend). This may be achieved through increasing twine diameter **d** while maintaining mesh bar length **l** in agreement with the requirements of regulations and conventions.

In fishing practice there are situations in which extending the mesh bar may have an impact on an increase in the mesh opening and a better selectivity of trawl codends. This may be the case during the hauling in of the trawl, when the velocity of the codend with respect to water decreases or when the catch is in part taken out of the codend, while the rest remains in the codend floating in the water – the meshes are wide open.

## 6. Final remarks.

The model of trawl codend used for calculations enables optimization of codend constructions according to the requirements of designers and the strategy of fishing for a given species, making it also possible for juvenile fish to escape, i.e.,

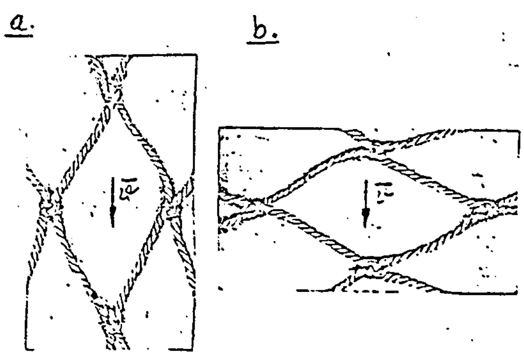


Fig. 4. Free meshs of the web:
a. situated in a standard way,
b. turned by an angle of 90°.

increasing codend selectivity. This may be achieved through a choice of codend construction with appropriate coefficients l/d and no/n for coefficients of mesh openings of codend nets observed in practice. The construction should be characterized by a possible large normal velocity of water outflow from the codend while observing all the necessary regulations and conventions with respect to the codend web.

Mechanical properties of the net mesh show that it is anisotropic, i.e., has no identical properties (here mechanical) in all directions. Because of the method of making the knot this is especially true about mesh openings close to marginal values. Thus, for instance, traditionally situated meshes close more easily under the influence of tensile forces than the meshes turned by $90^0$. For the latter, tensile forces first cause the meshes to open wide, and then, when the forces increase considerably, to close.

It appears from the system of hydrodynamic forces acting upon the trawl codend and observations of trawl behaviour in water that for a standard positioning of the web (meshes) in the codend, standard (encountered in fishing practice) coefficients **l/d** and **no/n**, an attempt to attain mesh opening enabling a qualitative change of selectivity of the webs used for codend construction meets with great difficulties. Departing from standard values of coefficients characteristic for the codends used presently, greater normal velocities of water outflow from the codend may be attained by decreasing coefficient l/d and increasing coefficient no/n or by increasing the mesh opening coefficient U1.

In connection with the observed anisotropy of the net meshes, in order to force a greater mesh opening, I propose the use of codends made of traditional webs used for codend construction, cut in such a way that the meshes in the codend are turned by an angle of $90^0$ (Fig. 4 – free meshs). The naturally folding, free web turned by an angle of $90^0$ has mesh bars situated perpendicularly to the codend axis, unlike in standard constructions, in which mesh bars are parellel to the longitudinal axis of the codend (theoretical direction of water inflow into the codend). At the moment of filling the codend with water, these two constructions will be subjected to different hydrodynamic forces because of the relationship between hydrodynamic drag coefficients of the webs and angles of attacks on mesh bars (Moderhak 1991). These forces are not too large as the flow around the web of codend situated at an angle close to zero in relation to the flow is turbulent (Ziembo 1993 a, b). It may be expected that the state which will become fixed as a result of the equilibrium of forces acting upon the mesh, in a fixed flow (during trawling with a constant speed) will be more favourable for a codend made of nets with meshes turned by $90^0$ than the state existing for a codend with meshes situated in a standard way. This may be expected on the basis of observation of mesh openings of the webs panels placed in a flow on the water surface. The openings of the turned meshes were greater than in those located in a standard way, which is connected with the construction of the knot. The openings of the turned meshes to a large degree depend on diameter d of the twine, used for web construction. This is especially visible for the webs made of double twine – elastic properties of the bent twine of the mesh bar in the vicinity of the knot play a great role here. The turned mesh has a more friendly shape for fish moving through it.

The analysis presented in the paper is a one-sided formulation of phenomena taking place in codends during flow of water coming from the inside of the belly through them. It does not take into account physical phenomena which may significantly influence the shape of codends and their selectivity in their entirety. The paper is a contribution to a brader look at codend construction and shows possibilities of direct influence of technique on stock conservation. It also shows that elastic constructions, such as codend or trawl, submit to fundamental laws of mechanics and hydromechanics to the same degree as rigid constructions. The problems presented here have not been sufficiently explored but because of the encouraging results of theoretical work should be verified by experimental tests, to determine the methods of improving the calculation model, and in the future obtain a tool not only for assisting trawl codend designing but also for evaluating the exiting constructions as regards their selective properties. The colaboration of fishing technique specialists, hydromechanics, and mechanics with ichthyologists in the field of environment protection may in a short time bring the desired results, manifesting themselves in a reduction of extraction of undersized fish covered by legal protection.

## 7. References.


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