ТЕХНОЛОГИЧЕСКИЕ ПРОЦЕССЫ, МАШИНЫ И АППАРАТЫ ДЛЯ ПЕРЕРАБОТКИ ВОДНЫХ БИОРЕСУРСОВ

TECHNOLOGICAL PROCESSES, MACHINES AND APPARATUS FOR PROCESSING AQUATIC BIORESOURCES

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Empirical dependences of the hydrodynamic drag coefficient of cod-ends made of T0 and T90 netting

Alexander A. Nedostup*✉, *Karina V. Konovalova

Kaliningrad State Technical University,
Kaliningrad, Russia, nedostup@klgtu.ru✉

Abstract. Cod-ends are cylindrical netting structures, which are made of nettings of different material and mesh rotation, it can be a traditional T0 or rotated by 90° – T90. Cod-ends consist of a jacket, the mesh pitch of which is set by fisheries regulations or conventions of a particular fishing area, and the cod-end itself. The cod-end made of ropes is surrounded by a frame for strength. In some cases, in coastal fisheries and inland waters, only the bag without the jacket and frame is used, while the bag itself performs several functions: catching hydrobionts in accordance with fishing regulations and holding the catch. Such cod-ends are used for scientific purposes in the trawl fishery for ruffed grouse (*Coregonus albula*) in lake Vishtynetskoe, Kaliningrad region. Retention qualities of cod-ends are connected with their selectivity, it means retention of those hydrobionts, which can be removed from the water body without damaging aquatic organisms and without undermining biomass of coastal waters, lakes and reservoirs. As a rule, mesh T0 has less selective properties in comparison with T90, as in netting T90 there are no sharp angles of contact between the ropes of one mesh, which ensures that hydrobionts are not clamped in it, in addition, such netting is better from the point of view of catchability to hold hydrobionts with an oval body. Also cod-ends with netting T90 have less hydrodynamic resistance compared to netting T0, which positively affects the hydrodynamic resistance of the trawl system itself and cod-ends made of netting T90 contribute to the preservation of the cylindrical shape of the cod-end in the process of trawling and catch retention, this is due to the shape of the mesh and physical and mechanical properties of the ropes from which the netting of the cod-end is made. In the course of the research, empirical dependencies of the coefficient of hydrodynamic resistance of cod-ends made of netting T0 and T90, material polyamide were obtained. The least coresistance was shown by kapron cod-ends made of netting T90. The resistance of such bags is 11% less than traditional cod-ends.

Keywords: cod-end, mesh, T0, T90, hydrodynamic resistance, empirical dependencies

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Научная статья

Эмпирические зависимости коэффициента гидродинамического сопротивления траловых мешков, изготовленных из дели Т0 и Т90

Александр Алексеевич Недоступ*✉*, Карина Витальевна Коновалова

Калининградский государственный технический университет,
Калининград, Россия, nedostup@klgtu.ru✉

Аннотация. Траловые мешки представляют собой сетные цилиндрические конструкции, которые изготовлены из дели различного материала и поворота ячей, это может быть традиционная Т0 или дель, повернутая на 90° – Т90. Траловые мешки состоят из рубашки, шаг ячеи которой устанавливается правилами рыболовства или конвенциями того или иного района промысла, самого тралового мешка. Траловый мешок для прочности окружает каркас, который изготавливается из канатов. В некоторых случаях в прибрежном рыболовстве и во внутренних водах используют только мешок, без рубашки и каркаса, при этом сам мешок выполняет несколько функций: облов гидробионтов в соответствии с правилами рыболовства и удержание улова. Такие траловые мешки применяются в научных целях при облове ряпушки (*Coregonus albula*) в оз. Виштынецкое Калининградской области. Удерживающие качества траловых мешков сопряжены с их селективностью, это означает удержание тех гидробионтов, которых возможно изымать из водоема, причем не повреждая самих водных организмов и не подрывая биомассу прибрежных вод, озер и водохранилищ. Как правило, дель с ячеей Т0 имеет меньшие селективные свойства по сравнению с делью Т90, т. к. в дели Т90 нет острых углов соприкосновения веревок одной ячеи, что предотвращает зажимание в ней гидробионтов, к тому же такой делью лучше, с точки зрения уловистости, удерживать гидробионты с овальным телом. Также траловые мешки с делью Т90 имеют меньшее гидродинамическое сопротивление по сравнению с делью Т0, что позитивно влияет на гидродинамическое сопротивление самой траловой системы, и траловые мешки, изготовленные из дели Т90, способствуют сохранению цилиндрической формы тралового мешка в процессе траления и удержания улова, это связано с формой ячеи и физико-механическими свойствами веревок, из которых изготовлена дель тралового мешка. В ходе проведения исследований получены эмпирические зависимости коэффициента гидродинамического сопротивления траловых мешков, изготовленных из дели Т0 и Т90, материал полиамид. Меньшее сопротивление показали капроновые траловые мешки, изготовленные из дели Т90. Сопротивление таких мешков на 11 % меньше традиционных траловых мешков.

Ключевые слова: траловый мешок, ячея, Т0, Т90, гидродинамическое сопротивление, эмпирические зависимости

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Introduction

Preserving the diversity of hydrobionts of the World Ocean, and catching the necessary mass of them is a priority task of pro-industrial fishery. The connection of the two tasks is reduced to the reasonable design and application of cod-ends of different depth and bottom trawls to retain hydrobionts in the cod-end [1]. Cod-ends are netting cilindrical structures which are made of netting of different material and mesh rotation, it can be traditional T0 and with 90° T90 rotation. Cod-ends consist of a jacket, the mesh pitch of which is set by fishing regulations or conventions of a particular fishing area, the cod-end itself, the mesh of which is larger than the mesh pitch of the jacket and by a factor of two, three or four, with a multiple, as a rule, a netting with a larger diameter is chosen and may consist of two ropes (Fig. 1).

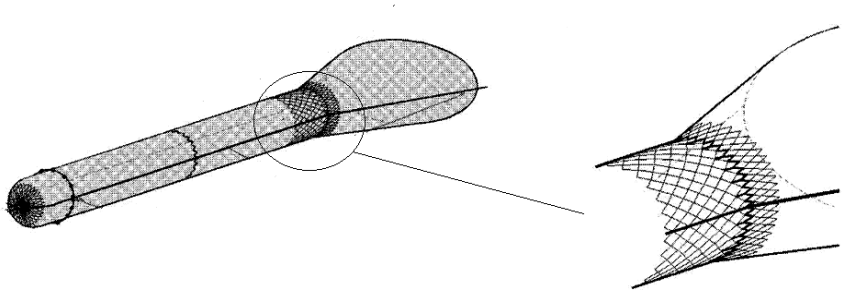


Fig. 1. Cod-end

For strength, a frame is built on top of the bag, which is made of ropes. In some cases, in coastal fisheries and inland waters, only the bag without the jacket and frame is used, with the bag itself performing several functions: trawling for hydrobionts in accordance with fishing regulations and retaining the catch. Such cod-ends are used for scientific purposes when fishing for ruffed grouse (*Coregonus albula*) in Lake Vishtynetskoe, Kaliningrad region. Retention qualities of cod-ends are connected with their selectivity, it means retention of those hydrobionts, which can be removed from the water body without damaging aquatic organisms and without undermining the biomass of coastal waters, lakes and reservoirs. As a rule, netting with T0 mesh has less selective properties in comparison with netting T90, as in netting T90 there are no sharp angles of contact of ropes of one mesh, which provides not clamping in it hydrobionts, besides such netting is better from the point of view of catchability to hold hydrobionts with an oval body in the cross-section. Also cod-ends with T90 contribute to the preservation of the cylindrical shape of the cod-end in the process of trawling and catch retention, this is due to the shape of the mesh and physical and mechanical properties of the ropes from which the netting of the cod-end is made [2-4].

The following factors should be considered in the design of cod-ends:

– mesh opening;
– shape of the cod-end;
– rope strength;
– knot strength;
– rope material.

The mesh opening is related to the shape of the cod-end and rope material. The strength of the ropes is selected from the hydrodynamic resistance of the cod-end and the weight of the catch attributed to the ropes in the mesh, taking into account their material and the rope safety factor specified by the designer. The strength of the knots for the T90 is an important problem that can only be solved by selecting knots that can withstand the required load by experimentation on experimental units. The material of ropes used to make cod-ends is diverse, it can be polyamide, polyethylene, polyester etc. There can be mixed material of rope fibers, there can be both polyamide and polyethylene fibers in one rope in percentage ratio. In all cases, the main physical and mechanical property of ropes is elasticity, which can be longitudinal, transverse and torsional. In our case, for the mesh shape, it is useful to know the bending strength of ropes E, on which the mesh shape T90 depends.

The hydrodynamic resistance of the cod-end has the greatest influence on the mesh shape, in addition to the given mesh parameters [5]. Scientists from many countries are studying this issue [3, 6, 7].

When justifying the choice of a cod-end for multi-depth or bottom trawls with T0 or T90 mesh, it is necessary to take into account all factors that influence the shape of the trawl structure, in particular the cod-end. In the article the influence of cod-end mesh shape on hydrodynamic resistance is considered. In this case the material of ropes polyamide is chosen, this material has proved itself well at manufacturing of nettings, and, having high elasticity, which fibers allow ropes to take the form of a mesh, which is necessary for designers and operators of trawls.

Fig. 2 shows the traditional T0 and 90-degree T90 mesh shapes.

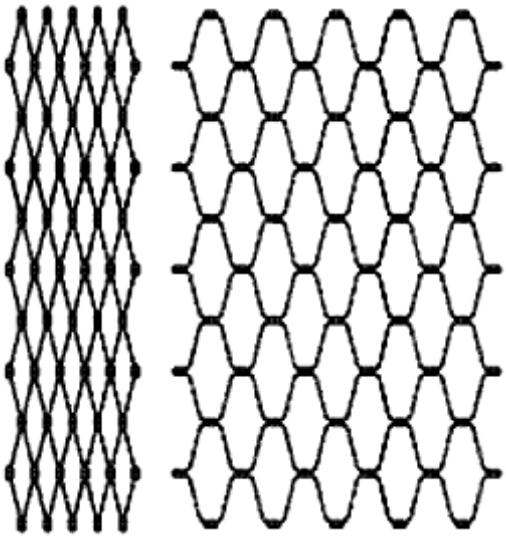


Fig. 2. Mesh shape T0 and T90

When investigating the hydrodynamics of cod-ends, attention should be paid to the shape in plan of the ropes and the continuity of these structures. Let's introduce the assumption that the continuity of netting T0 and T90 is determined by the same formula:

$$F_o = \frac{d}{au_x u_y}$$

where d – rope diameter; a – mesh pitch; u_x – planting coefficient for the length of the cod-end; u_y – planting coefficient for the height of the cod-end.

Problem statement

The research problem of the cod-end design problem of multi-depth and bottom trawls is based mainly on the search for a solution to the selectivity of cod-ends, in particular, to catch the necessary mass of commercial hydrobionts without damaging individuals.

When operating a multi-depth trawl with a T0 cod-end on Lake Vishtynetskoye [8], we encountered the problem of opening the cod-end. There was a problem of hydraulic support in the place of connection of the cod-end to the end part of the trawl (see Fig. 1). This

problem was solved by turning the cod-end netting from T0 to T90. The experiments were conducted at the quarry of Gvardeysky settlement.

The effects of netting deployment in the fishery could not be determined due to lack of advisory equipment (video and fish entry sensors in the cod-end).

In order to make an informed decision on the choice of T0 or T90 netting spread, it was decided to conduct a series of experiments with T0 and T90 cod-ends. In order to make an informed decision on the choice of T0 or T90 netting spread, it was decided to conduct a series of experiments with T0 and T90 cod-ends in Fischering Service hydrochannel. The parameters of the cod-end netting are given in Table 1.

Table 1

Characteristics of netting cod-ends

Mesh shape	*a*, mm	*d*, mm	*n*, mesh	*m*, mesh	Material
T0	8.0	1.0	320	200	Polyamide
T90					

A schematic of the cod-end experiments is given in Fig. 3.

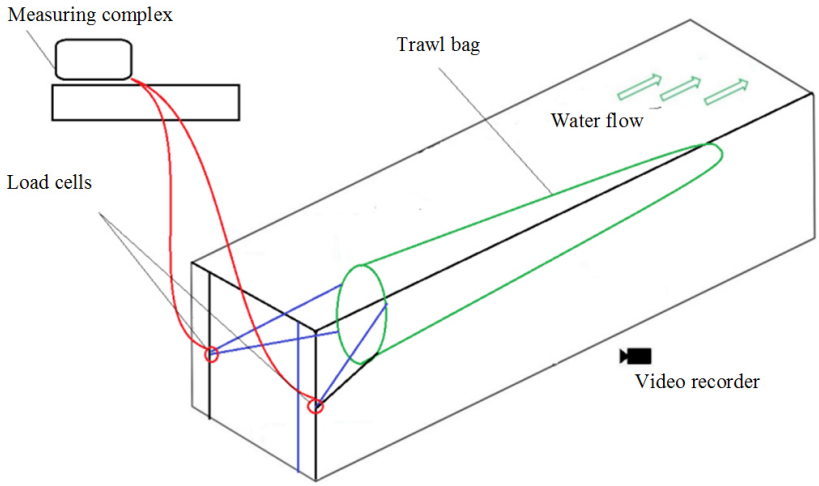


Fig. 3. Scheme of experiments with cod-ends

Fig. 3 shows the working section of hydrochannel "Fischering Service", a cod-end fixed on a hoop, which ensures opening of the cod-end with a given fit u_x. The hydrodynamic resistance was measured by the complex. Video recording of the cod-end with fixation of its opening, as well as the opening of the mesh was carried out by a video camera.

The shape of cod-ends depends on the opening of the place of their connection with the end part (see Fig. 1), in order to set the opening of cod-ends, it was decided to put the upper part of the cod-ends on metal hoops of different diameter *D*. The experiments were carried out with the use of measuring equipment of hydrochannel "Fischering Service" hydrochannel, cod-ends were fixed on sliding blades with strain gauges installed on them. Characteristics of cod-ends are given in Table 2.

Table 2

Characteristics of cod-ends

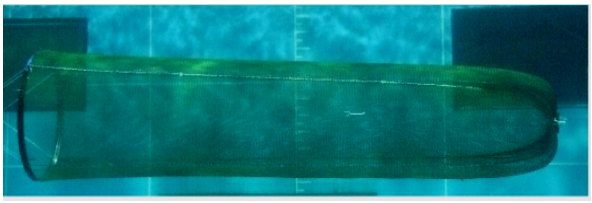
D, mm	u_x	u_y	F_o
350	0.215	0.977	0.596
540	0.331	0.944	0.4
640	0.393	0.92	0.346

Based on the data in Tables 1 and 2, two cod-ends were constructed and alternately seated on metal hoops of different diameters to ensure different seating and netting continuity.

Methods

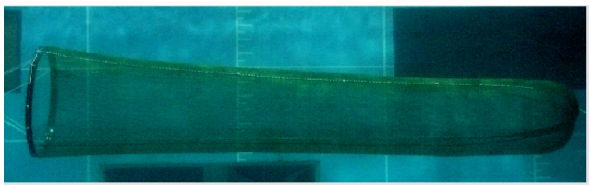
Cod-end experiments showed a clear dependence on cohesion and mesh shape. In turn, to determine the approximating dependencies, it is necessary to select the approximation coefficients so that the correlation

of the dependent factors is clear and the hydrodynamics of the process is understood. Fig. 4 shows two cod-ends, which have the same continuity F_o = 0.346, and are planted on the same metal hoop, the diameter of which is D = 640 mm.



a

Fig. 4. Photos of cod-ends T90 (*a*)



b

Fig 4 (ending). Photos of cod-ends T0 (*b*),
D = 640 mm, F_o = 0.346

During the experiments, the values of hydrodynamic drag coefficient of cod-ends were obtained – c_x (see Table 3).

Table 3

Values of structural and force characteristics of cod-ends

Mesh shape	F_o	Re*	$c_x \cdot 10^{-3}$
T0	0.596	750	9.22
		1 125	5.85
		1 563	3.83
	0.4	750	12
		1 125	7.23
		1 563	4.89
	0.346	750	13
		1 125	8.38
		1 563	5.81
T90	0.596	750	8.27
		1 125	5
		1 563	3.56
	0.4	750	10
		1 125	6.45
		1 563	4.59
	0.346	750	13
		1 125	7.96
		1 563	5.66

* Re – Reynolds number.

To approximate the values, which are presented in Table 3 by the dependence of the following form:

$$c_x = f(\mathrm{Re}, F_o, k) \qquad (1)$$

where k – is the coefficient depending on the mesh shape T0 or T90, it is necessary to make the following calculations:

– approximation of the form

$$c_x = f(\mathrm{Re}, F_o), \qquad (2)$$

for cod-ends separately T0 and T90;

– approximate the form

$$k = f(T)$$

where T – is the shape of the mesh T0 or T90.

In order to simplify the approximation dependence in terms of its form, as well as to minimize the approximation error

$$\delta \rightarrow \min$$

where δ – is the approximation error, it was decided to use an index function of the form:

$$c_x = kF_o\,\mathrm{Re}^a \qquad (3)$$

where a – is the approximation coefficient.

Tables 4, 5 show the values of the approximation coefficients (3) and the values of its error.

Table 4

Values of approximation coefficients (3) and values of its error for T0

Mesh shape	F_o	k	a	δ, %
T0	0.596	12.9	–1.1	3.8
				2.9
				–3.4
	0.4	16.4		3.3
				0.2
				2.9
	0.346	19		0.7
				0.2
				–0.3

Table 5

Values of approximation coefficients (3) and values of its error for T90

Mesh shape	F_o	k	a	δ, %
T90	0.596	11.8	–1.1	1.9
				–3.8
				–1.6
	0.4	14.9		–0.7
				–1.7
				0.5
	0.346	18.4		0.7
				–1.8
				0.2

Based on Table 4, the approximating dependence of the form (2) is presented in the form of

$$c_x = kf\left(F_o\right)\mathrm{Re}^{-1,1}$$

on Fig. 5 shows the data of the coefficient k depending on F_o.

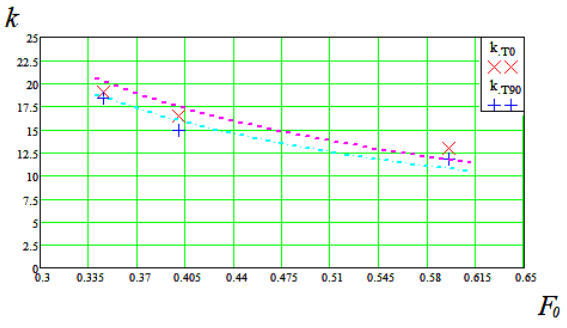


Fig. 5. Dependencies k on F_o

The approximating dependence of the form (1) is presented in the following form:

$$c_x = k\,{}^{\mathrm{T0}=7}_{\mathrm{T90}=6,4}\,F_o^{-1}\,\mathrm{Re}^{-1,1} \qquad (4)$$

where $k = 7$ for T0; $k = 6.4$ for T90.

Results and discussion

As a result of approximation of dependence of the form (1), the relationship between geometric and force parameters of the netting T0 and T90 is obtained, the approximation error does not exceed 9%.

Based on the obtained dependence (4), the resistance of the cod-end made of T90 netting is 11% less than the cod-end made of T0 netting. Dependence (4) is valid for cod-ends made of polyamide.

Conclusion

The conducted research has allowed to obtain a clear dependence of the hydrodynamic drag coefficient of netting, from which cod-ends are made.

The research was carried out within the framework of the state assignment on the theme “Development of physical, mathematical and predictive models of the processes of bottom and multi-depth trawl complexes operation”.

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Information about the authors / Информация об авторах

Alexander A. Nedostup – Candidate of Technical Sciences, Assistant Professor; Head of the Department of Commercial Fishery; Kaliningrad State Technical University; nedostup@klgtu.ru

Karina V. Konovalova – Postgraduate Student of the Department of Commercial Fishery; Kaliningrad State Technical University; karina.konovalova@klgtu.ru

Александр Алексеевич Недоступ – кандидат технических наук, доцент; заведующий кафедрой промышленного рыболовства; Калининградский государственный технический университет; nedostup@klgtu.ru

Карина Витальевна Коновалова – аспирант кафедры промышленного рыболовства; Калининградский государственный технический университет; karina.konovalova@klgtu.ru