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THE METHOD OF CALCULATION OF FORCE AND GEOMETRICAL CHARACTERISTICS OF BOTTOM TRAWLS

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Works are devoted to research of force and geometrical characteristics of full-scale and physical models bottom trawl

- ***Shorigin,*** *1933;*
- ***Baranov,*** *1969;*
- ***Fridman,*** *1957;*
- ***Rozenshtein,*** *1966;*
- ***Korotkov,*** *1970;*
- ***Brandt,*** *1970;*
- ***Koyama,*** *1970;*
- ***Bidenko,*** *1971;*
- ***Amagai,*** *1972;*
- ***Galbraith,*** *1983;*
- ***Dudko,*** *1986;*
- ***Tait,*** *1988;*
- ***Lonnevik,*** *1988;*
- ***Gunnarsson,*** *1988;*
- ***Ferro,*** *1988;*
- ***Robertson,*** *1990;*
- ***Fiorentini,*** *1999, 2004;*
- ***Fuwa,*** *2003;*
- ***Matsushita,*** *2005;*
- ***Weinberg,*** *2006;*
- ***Mizurkin,*** *2010;*
- ***Nedostup,*** *2011.*

Actual problems of commercial fishery are decisions of tasks of their mechanics and catching

From among tasks of mechanics bottom trawl (BT) the method of calculation of force and geometrical characteristics of a trawl is below described.

To force and geometrical characteristics we shall relate the most important with which it is necessary to provide at designing BT:

- ***drag of net of a trawl;***
- ***vertical and horizontal disclosings of a mouth of a trawl (on a tug).***

Process of movement bottom trawl is considered in stationary statement without taking into account the catch.

The purpose of the present work will consist in development of a method of calculation of force and geometrical characteristics bottom trawl (BT)

The drag of net of a trawl R_x is defined under the formula:

$$R_x = c_x \frac{\rho v^2}{2} F_н \qquad (1)$$

$$c_x = f\left(F_o, \alpha\right), \quad \mathrm{Re} \geq 600 \qquad (2)$$

- c_x – drag coefficient, determined directly on result of experiments or calculated on the basis of experimental data;
- ρ – water density;
- v – speed of towage of a trawl;
- $F_н$ – projection area of netting twine;
- F_o – the relative area of a trawl net;
- α – the attack angle of a trawl net.

Drag coefficient c_x a trawl net

The relative area of a trawl net F_o it is defined on expression:

$$F_o = \frac{d_c}{a_c} \frac{1}{u_{xc} u_{yc}} \tag{3}$$

$$c_x = k\alpha - 0{,}09 \tag{4}$$

- d_c – the average weighed value of diameter of threads and ropes of a trawl net;
- a_c – the average weighed value of a mesh a trawl net;
- u_{xc} – the average weighed value of landing factor of a trawl net in cross-section section;
- u_{yc} – the average weighed value of landing factor of a trawl net in longitudinal section;
- k – dimensional coefficient, with dimensionless (1/deg).

The formula (4) is fair in a range $5\text{deg} \leq \alpha \leq 16\text{deg}$.

Attack angle α of a trawl net

$$\alpha = A + 110e^{-6,74F_o}\left(\omega - 0,02\right) \tag{5}$$

$$\omega = cP \tag{6}$$

- A – an increment of attack angle of a trawl net, depending on dimensionless forces.

$$A = f\left(\underbrace{\frac{R_{yd}}{R_x + R_{xo}}}_{\tau}, \underbrace{\frac{Q}{R_x + R_{xo}}}_{\xi}, \underbrace{\frac{kG}{R_x + R_{xo}}}_{\chi}\right)$$

- R_{yd} – lift force of a otter board;
- R_{xo} – resistance of detail equipment of head rope and ground rope;
- Q – lift force or buoyancy a detail equipment of head rope;
- G – weight in water ground rope;
- k – the parameter dependent on relation Q/G, $k=f(Q/G)$.

The form of a mouth of a trawl

$$\omega = \frac{F_u}{F_f} = \frac{\pi HLd_c}{4a_c F_f} = cP \qquad (7)$$

$$F_u = \frac{1}{2}\pi(H - h_k)\frac{L}{2} + \frac{1}{2}\pi h_k \frac{L}{2} = \frac{\pi}{4}HL \qquad (8)$$

- F_u – the area of a mouth of a trawl on a tug $F_u=\pi LH/4$ (H - vertical disclosing of a trawl on a tug; L - horizontal disclosing of a mouth of a trawl on a tug);
- F_f – the fictitious area of a trawling environment, $F_f=a_cF_н/d_c$;
- c - coefficient, $c=8\lambda/(3\lambda\lambda+2\lambda+3)$;
- h_k - height of veranda (diameter of bobbin);
- P - design parameter of trawl net.

$$\lambda = f(\tau, \xi, \chi), \qquad \lambda = 2(H - h_k)/L$$

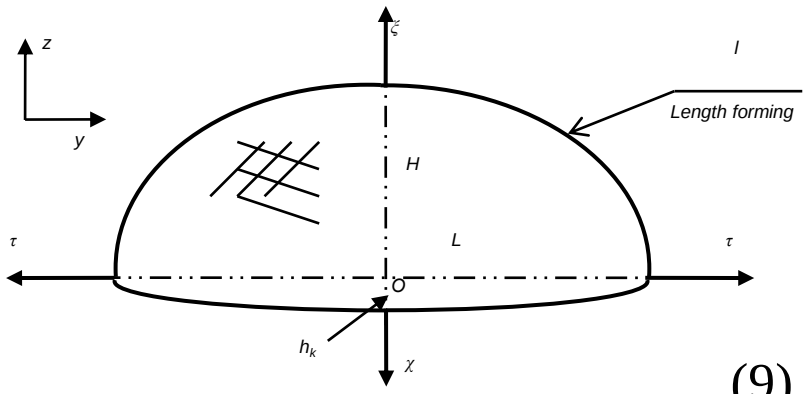


Figure 1

$$l \approx \frac{\pi}{2}\left(1{,}5(H + L) - \sqrt{(H - h_k)\frac{L}{2}} - \sqrt{h_k \frac{L}{2}}\right) \qquad (9)$$

$$l = l_1 + l_2 \qquad (10)$$

where l_1 - length in landing top netting BT on a tug;

l_2 - length in landing bottom netting BT on a tug.

Force, constructive and geometrical characteristics full scale BT

Table 1. The force and geometrical characteristics of full scale bottom trawls

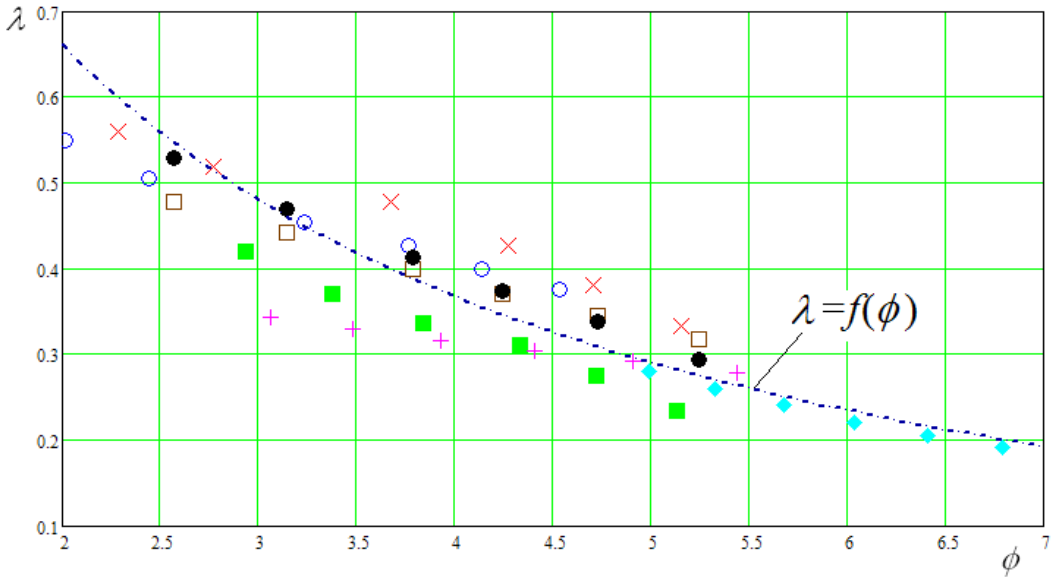
№ BT	V, m/s	H, m	L m	R_x, kN	c_x	$F_н$, m^2	F_o	P x 10^{-4}	τ	ξ	χ
41,7/39,6	2,0	6,0	26,0	82,7	0,21	200,0	0,384	3,37	0,128	0,026	0,043
30,8/32,1	1,5	6,0	20,0	38,5	0,212	162,0	0,231	11,28	0,158	0,058	0,072
19,8/27,3	1,54	2,35	10,5	36,0	0,198	146,6	0,192	21,6	0,138	0,033	0,048
31,0/27,4	1,85	3,2	17,8	53,4	0,2	149,2	0,196	21,9	0,152	0,031	0,038
17,4/21,1	1,59	1,76	10,5	35,9	0,2	136,7	0,204	20,32	0,147	0,026	0,034
34,8/38,3	1,44	4,8	17,5	12,0	0,245	43,9	0,153	12,35	0,37	0,174	0,123
21,2/32,5	1,44	4,2	14,0	11,6	0,238	44,9	0,119	12,1	0,371	0,175	0,114

The note: The note: for BT: 41,7/39,6; 30,8/32,1; 31,0/27,4; 34,8/38,3 and 21,2/32,5 - h_k=500mm; for BT: 19,8/27,3 and 17,4/21,1 - h_k=400mm.

Results and discussion

$$\lambda = e^{1-\sqrt{\varphi}} \qquad (11)$$

The formula (11) is fair in a range of physical conditions $0,2 \le \lambda \le 0,65$ and $2,0 \le \varphi \le 7,0$ for BT. On fig. 2 dependence $\lambda = f(\varphi)$ is represented. The approximation (coefficient of correlation in a range $0,92 \le RR \le 0,966$, a relative error of 10%).



$$\varphi = \frac{2\tau}{\xi + \chi} = \frac{2R_{yd}}{Q + kG} \qquad (12)$$

$$k = 1 - e^{-2\left(\frac{Q}{G}\right)} \qquad (13)$$

Figure 2. Dimensional dependence $\lambda = f(\varphi)$.
× - BT 41,7/39,6; ○ - BT 30,8/32,1; ■ - BT 19,8/27,3; + - BT 31,0/27,4; ♦ - BT 17,4/21,1; □ - BT 34,8/38,3; ● - BT 34,8/38,3

Coefficient *k*

Table 2 Value of coefficient *k*

Parameters	№ bottom trawl						
	41,7/39,6	30,8/32,1	19,8/27,3	31,0/27,4	17,4/21,1	34,8/38,3	21,2/32,5
Q/*G*	0,2	0,56	0,173	0,582	0,421	0,308	0,308
k	0,33	0,7	0,25	0,71	0,55	0,2	0,2

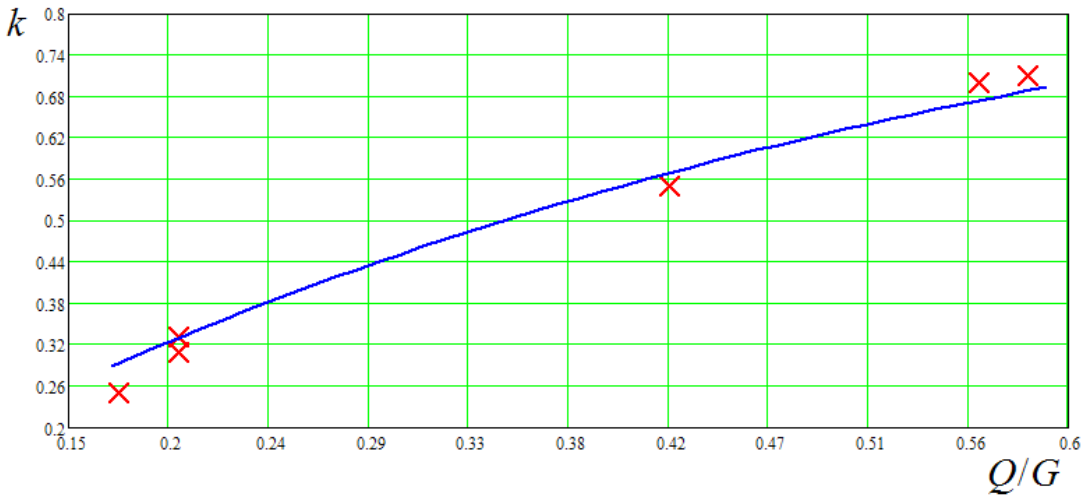


Figure 3

Dimensional dependence $k=f(Q/G)$

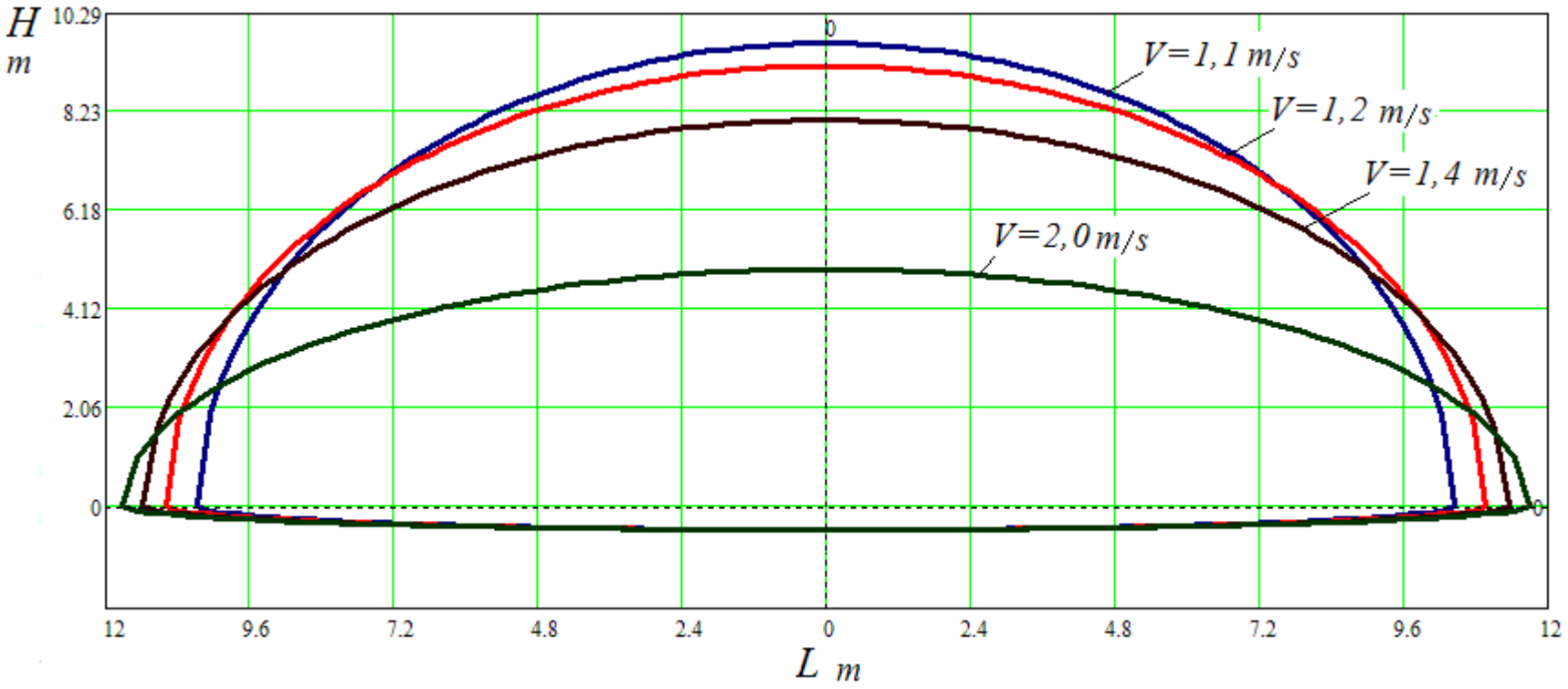
Example

Table 3. Characteristics full scale BT

№ BT	Parameters													
	d_c mm	F_o	$F_н$ m^2	P x 10^{-4}	V m/s	Re	F_d m^2	Q kN	G kN	c_x	R_{xr} kN	H_r m	L_r m	F_u m^2
41,7/39,6	4,1	0,384	200,0	3,37	1,1	4318	5,5	2,46	12,36	0,171	21,4	10,1	20,9	166,0
					1,2	4711				0,177	26,3	9,7	22,0	166,0
					1,3	5103				0,181	31,7	9,1	22,7	163,0
					1,4	5496				0,184	37,4	8,5	23,4	157,2
					1,5	5889				0,187	43,6	8,0	24,0	150,1
					1,6	6281				0,189	50,1	7,4	24,5	142,3
					2,0	7851				0,194	80,3	5,6	25,9	110,5
19,8/27,3	4,53	0,192	146,6	21,6	1,1	4700	3,5	1,36	7,9	0,166	15,3	4,05	9,36	30,0
					1,2	5127				0,17	18,6	3,8	9,7	28,7
					1,3	5554				0,173	22,3	3,5	10,0	27,4
					1,4	5982				0,175	26,2	3,23	10,2	25,8
					1,5	6409				0,177	30,4	2,98	10,4	24,3
					1,54	6580				0,178	32,3	2,87	10,5	23,6
					1,6	6836				0,179	34,9	2,73	10,6	22,7
31,0/27,4	4,56	0,196	149,2	21,9	1,1	4700	4,5	1,8	3,1	0,158	14,9	6,7	16,0	84,0
					1,2	5127				0,165	18,5	6,2	16,5	81,0
					1,3	5554				0,17	22,3	5,7	17,0	76,7
					1,4	5982				0,174	26,4	5,3	17,4	72,1
					1,5	6409				0,176	30,8	4,8	17,8	67,5
					1,6	6877				0,178	35,4	4,4	18,0	62,8
					1,84	7909				0,182	47,7	3,5	18,6	52,1

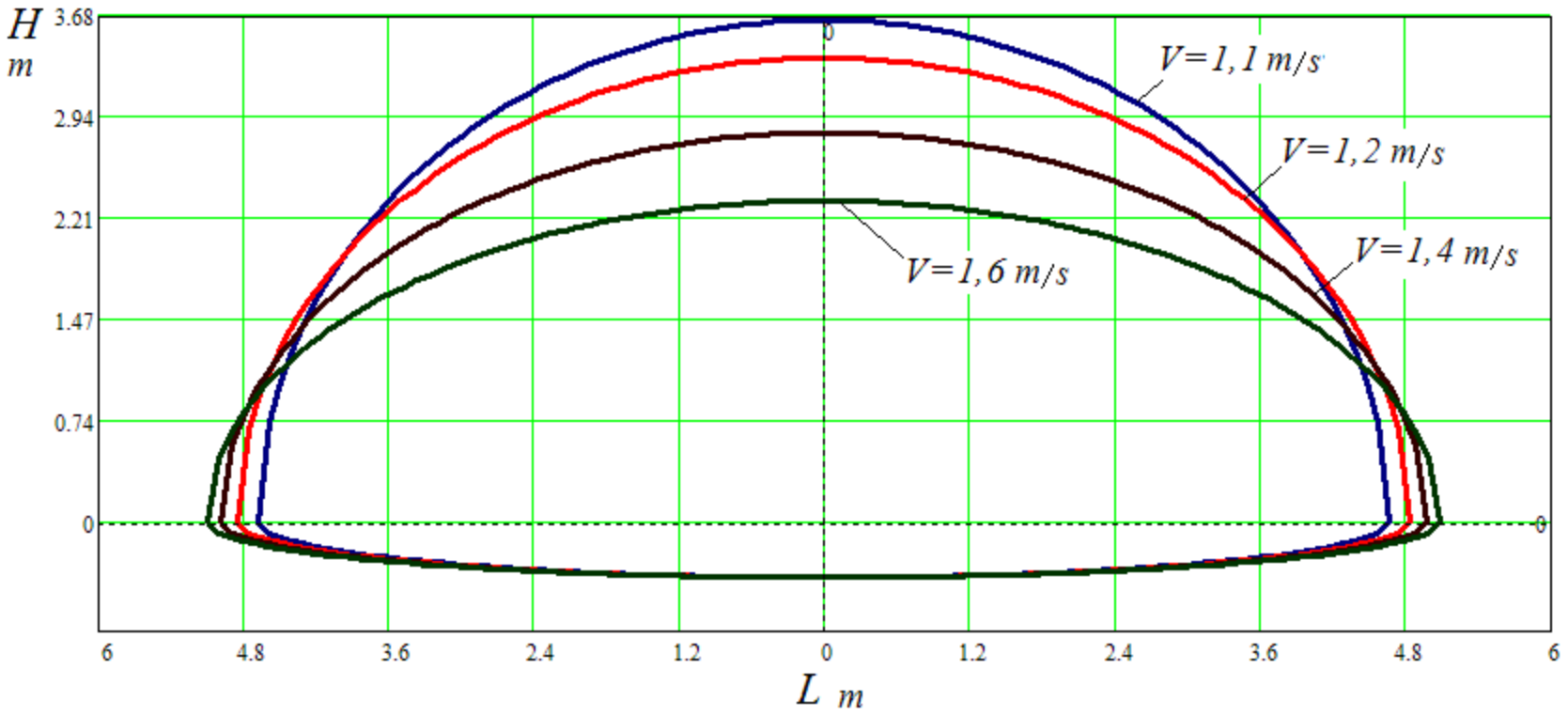
Example

The forms of a mouth full scale BT 41,7/39,6



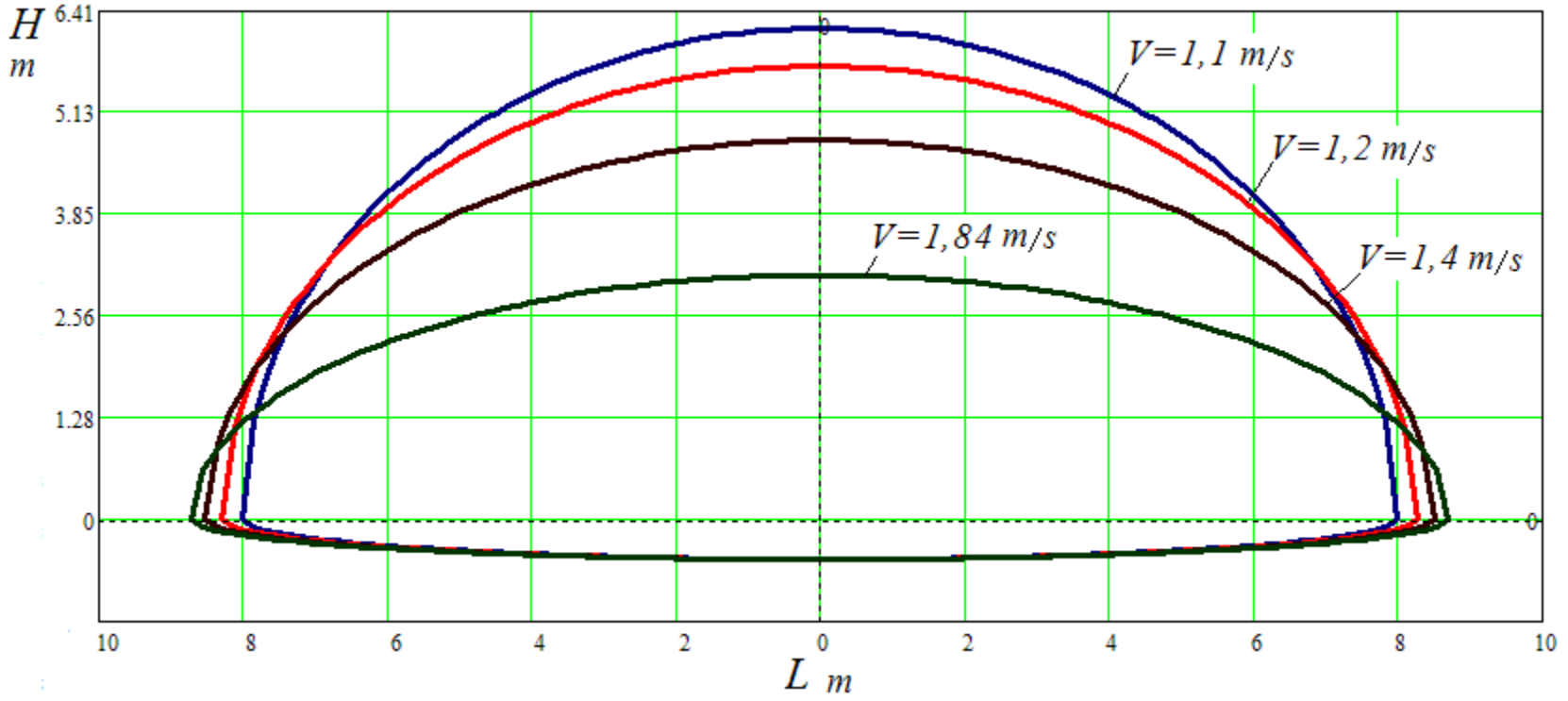
Example

The forms of a mouth full scale BT 19,8/27,3

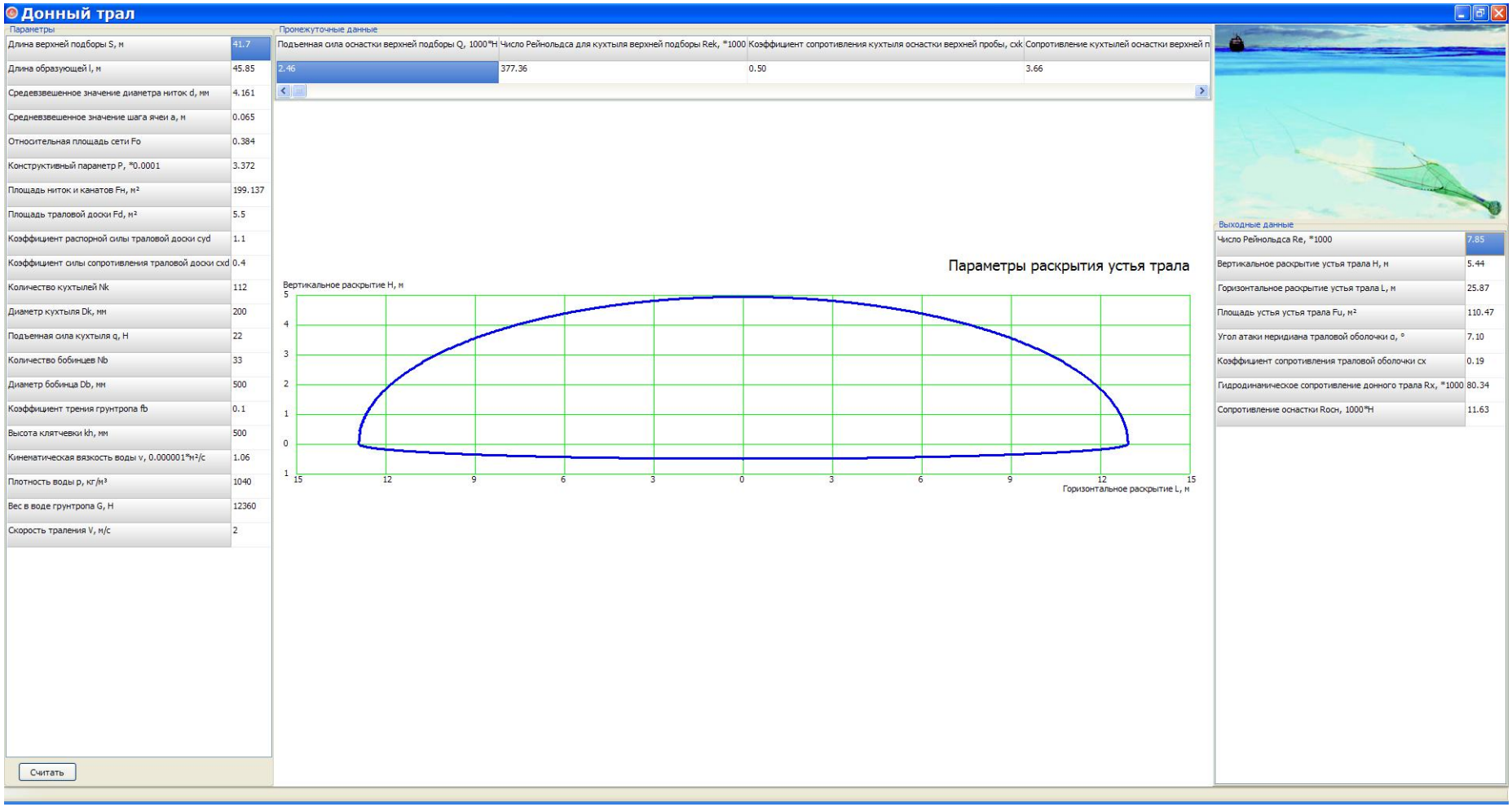


Example

The forms of a mouth full scale BT 31,0/27,4



The computer program «Bottom trawl»



The method allows:

- 1. To define force of drag R_x trawl net BT.
- 2. To define characteristics of disclosing of mouth BT H and L.
- 3. To define necessary characteristics of details of equipment for maintenance of disclosing of mouth BT.
- 4. To define on set sizes H and L drag force of trawl net has made parts of BT R_x.
- 5. To provide with parameters of equipment selection of a trawl necessary attitude H/L for successful of catch objects of a craft.
- 6. To define necessary speed trawling of BT V at maintenance of condition $V_k \leq V$ (V_k - cruiser speed of a fish) in view of sizes H and L.
- 7. To define characteristics netting of trawl net of BT for maintenance of conditions: $R_x \rightarrow \min$, $H \rightarrow \max$ and $L \rightarrow \max$ under condition of maintenance of catching qualities of a trawl.

To pick up equipment with account Q/G for an effective craft of ground kinds of fishes.

Thank you for attention!