10th International Workshop in University of Split
DEMaT'2011

Rules of physical modelling of dynamic processes of fishery

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Dynamic processes of fishery

- *towing of trawl with acceleration;*
- *transitive of trawling;*
- *immersing purse seine;*
- *immersing Danish seine;*
- *extension purse seine;*
- *extension of Danish seine;*
- *immersing set-nets;*
- *immersing and extension long line;*
- *etc. where there are acceleration.*

} **It is not static process of fishery**

Rules of modelling of *static* processes of fishery

- *Tauti, 1934;*
- *Dickson, 1959;*
- *Christensen, 1975;*
- *Fridman, 1981;*
- *O'Neill, 1993;*
- *Hu et al., 2000.*

→ **Rules of modelling of *static* processes of fishery**

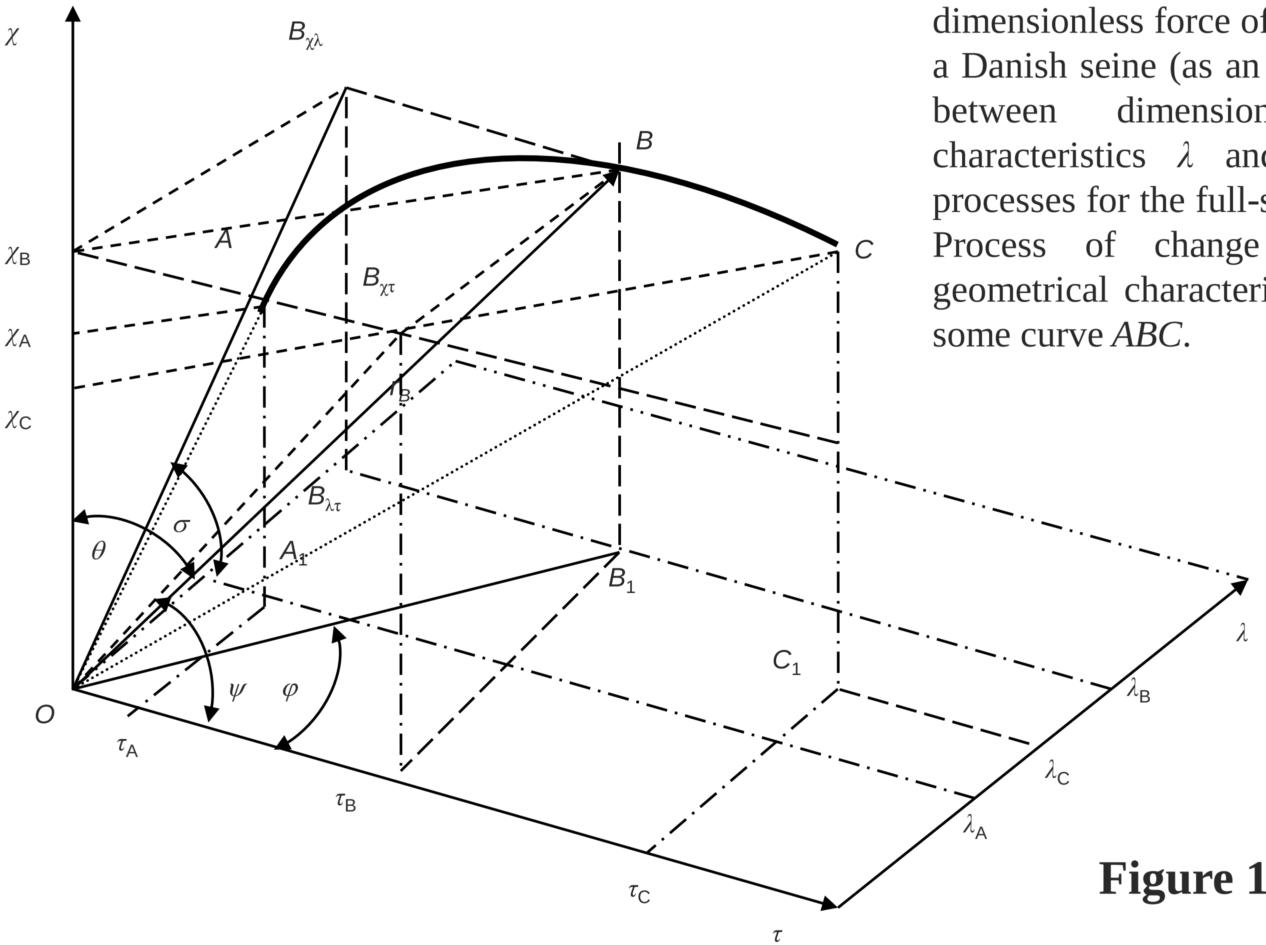
Note!

It is necessary to note, that all fishing gears both in stationary, and in ***non-stationary*** modes. And rules of physical modelling in a static are not rules of modelling of ***dynamic*** processes which are the general, instead of individual rules of modelling.

⇛

Geometrical characteristics depend on **force** characteristics and on the contrary, and process proceeds in **time**.

All in a dimensionless kind



The first approach. Let's consider change of dimensionless force of a tension χ in rope at extension of a Danish seine (as an example). Let's define connection between dimensionless force χ, geometrical characteristics λ and time τ courses of dynamic processes for the full-scale of fishing gear and its model. Process of change of dimensionless force and geometrical characteristics in time can be presented as some curve *ABC*.

Figure 1. The dependence χ=f(τ,λ)

Let dimensionless force of a tension in rope at extension of a Danish seine χ and other characteristics at extension (etching) the instrument of fishing gears under the law

$$\left.\begin{aligned} \tau &= r\sin\theta\cos\varphi \\ \lambda &= r\sin\theta\sin\varphi \\ \chi &= r\cos\theta \end{aligned}\right\} \qquad (1)$$

where r - dimensionless radius; θ - angle $\angle T_B O B$; φ - angle $\angle t_B O B_1$.

$$\left.\begin{aligned} tg\psi &= \sin\psi/\cos\psi = \chi/\tau \\ tg\sigma &= \sin\sigma/\cos\sigma = \chi/\lambda \\ tg\varphi &= \sin\varphi/\cos\varphi = \lambda/\tau \end{aligned}\right\} \qquad (2)$$

where ψ - angle $\angle B_{\chi\tau} O t_B$; σ - angle $\angle B_{\chi\lambda} O B_{\lambda\tau}$.

$$\left.\begin{aligned} OB_1 &= \chi tg\theta \\ OB_1 &= \tau/\cos\varphi \end{aligned}\right\} \qquad (3)$$

$$\frac{\chi}{\tau} = \frac{1}{tg\theta\cos\varphi} \qquad (4)$$

Let dimensionless force of a tension in rope at extension of a Danish seine χ and other characteristics at extension (etching) the instrument of fishing gears under the law

Let's divide the left and right parts of expression (4) on τ, then

$$\frac{\chi}{\tau^2} = \frac{\cos\theta}{\sin\theta\cos\varphi} \cdot \frac{1}{r\sin\theta\cos\varphi} \qquad (5)$$

Let's increase the left and right parts of expression (5) on λ

$$\frac{\chi\lambda}{\tau^2} = \frac{\cos\theta}{\sin\theta\cos\varphi} \cdot \frac{r\sin\theta\sin\varphi}{r\sin\theta\cos\varphi} = \frac{\cos\theta\sin\varphi}{\sin\theta\cos^2\varphi} = \frac{tg\varphi}{tg\theta\cos\varphi} \qquad (6)$$

and from (2) we have

$$\frac{\chi\lambda}{\tau^2} = tg\psi tg\varphi \qquad (7)$$

and from (2) $tg\sigma = tg\psi / tg\varphi$. Dynamic similarity is not broken at maintenance of geometrical similarity: φ=idem, θ=idem, ψ=idem and σ=idem, then

$$\frac{\chi_f \lambda_f}{\tau_f^2} = \frac{\chi_m \lambda_m}{\tau_m^2} \qquad (8)$$

«*f*» - an index of the full-scale of fishing gear, «*m*» - an index of model of fishing gear

Then, we shall present expression (8) as

$$\frac{T_f S_f}{t_f^2} \cdot \frac{t_{\max f}^{\,2}}{T_{\max f} S_{\max f}} = \frac{T_m S_m}{t_m^2} \cdot \frac{t_{\max m}^{\,2}}{T_{\max m} S_{\max m}} \qquad (9)$$

where T - force of a tension in a present situation of time; S - length of rope in a present situation of time (any geometrical parameter of fishing gear); t - time; T_{max} - the maximal tension; S_{max} - initial length of rope or other; t_{max} - total time of duration of process.

Let's write down expression (9) as

$$\frac{t_{\max f}^{\,2}}{T_{\max f} S_{\max f}} = \frac{C_R C_l}{C_t^2} \cdot \frac{t_{\max m}^{\,2}}{T_{\max m} S_{\max m}} \qquad (10)$$

where C_R - scale of forces; C_l - linear scale; C_t - time scale.

What is it?

Let's note, that at observance φ=idem, θ=idem, ψ=idem and σ=idem, or

$$\frac{t_{\max f}^{2}}{T_{\max f} S_{\max f}} = \frac{t_{\max m}^{2}}{T_{\max m} S_{\max m}}$$

then on the basis (10) connection of scales of similarity can be written down as

$$\frac{C_R C_l}{C_t^2} = 1 \qquad (11)$$

Note! What is it?

$$\frac{TS}{t^2} = Fa = ma^2 \quad \Rightarrow \quad m_f a_f^2 = m_m a_m^2 = const$$

The second approach

The second approach. Definition of criteria of similarity on the basis π - theorems. The method of «zero dimensions» (π - the theorem) is known. Various processes (hydrodynamical, ground dynamical, friction, etc.) are considered. So by consideration of hydrodynamical processes it is possible to write down, that force of tension T in rope (as an example) at its extension will be function of the listed parameters

Further on the basis π - theorems receive criteria of similarity of dynamic processes of fishery. Let's result the basic two criteria of similarity Ne and Sh

$$\frac{C_R C_a}{C_k C_\rho C_d C_l^2 C_U^2} = 1 \qquad (12)$$

where C_d - scale of diameter threads, cords and ropes; C_a - scale of a mesh size; C_U - scale of speed; C_k - scale of drag coefficient at modelling the fishing gear, as complex system: «rope - equipment (otter board etc.) - the fishing gear» is accepted; C_{Fo}=idem - scale the relative area of a trawl net; C_ρ - scale of density of environment (water or etc.),

Connection of scales

$$\frac{C_U C_t}{C_l} = 1 \qquad (13)$$

Let's express from (13) scale of speed $C_U = C_l / C_t$ and we shall substitute it in the formula (12), then

$$\frac{C_R C_a C_t^2}{C_k C_\rho C_d C_l^4} = 1 \qquad (14)$$

Under condition of Fo=idem - relative area of a trawl net (Fridman, 1981) ($C_d = C_a$, $C_k = 1$ and ρ=idem ($C_\rho = 1$) we shall write down expression (14) as

$$\frac{C_R C_t^2}{C_l^4} = 1 \qquad (15)$$

Rules of modelling of *dynamic* processes of fishery

Let's result criterion of dynamic similarity (π - the theorem)

$$\frac{C_m C_U}{C_t C_R} = 1 \tag{16}$$

where C_m - scale of mass.

We shall equate (11) and (15)

$$\frac{C_R C_l}{C_t^2} = \frac{C_R C_t^2}{C_l^4} \quad \leftrightarrow \quad C_l^5 = C_t^4 \quad \text{or} \tag{17}$$

Rules of dynamic similarity of fishing systems, and also mechanical systems are proved. Scales of modelling of **dynamic processes of fishery** are received. With the account (11,13), we shall write down expression for definition of scale of:

time, speed, force, acceleration

$$C_t = C_l^{\frac{5}{4}} \qquad C_U = C_l^{-\frac{1}{4}} \qquad C_R = C_l^{\frac{3}{2}} \qquad C_\omega = C_l^{-\frac{3}{2}}$$

Scales of dynamical modelling

Scales of modelling of a trawls, purse seines, Danish seines, set-nets and et.:

$$C_U = C_l^{-\frac{1}{4}} \qquad (18)$$

$$C_R = C_l^{\frac{3}{2}} \qquad (19)$$

$$C_t = C_l^{\frac{5}{4}} \qquad (20)$$

$$C_\omega = C_l^{-\frac{3}{2}} \qquad (21)$$

where $C_\omega = C_l / C_t C_t$.

Scale of mass

With the account (18) - (21) from (16) we shall express scale of mass

$$C_m = \frac{C_R C_t}{C_U} = C_l^3 \qquad (22)$$

However, modelling hydrostatic forces it is necessary to take into account

$$C_\gamma = C_\rho C_g = \frac{C_m}{C_l^3} \qquad (23)$$

where C_γ - scale of volumetric weight of the fishing gear; C_g - scale of acceleration of a gravity, and C_g=1.
Proceeding from (22) and (23), we shall receive C_γ=1. Let's present expression (23) as

$$C_l^3 = \frac{C_m}{C_\gamma} \qquad (24)$$

Scales of force and mass

also we shall present expression (16) or (22) as

$$C_m C_l^{-3} = 1 \tag{25}$$

then we shall present expression (25) with the account (24) as

$$\frac{C_m}{C_\gamma} C_l^{-3} = 1 \tag{26}$$

Let's write down Arhimed's law as

$$mg = q + \gamma_w V$$

where *m* - mass of a fishing gear; *q* - weight in water of a fishing gear; γ_w - volumetric weight of the environment (water); *V* - volume of a fishing gear.
Or scale of forces

$$C_R = \frac{m_m g}{m_f g} = \frac{m_m}{m_f} = \frac{q_m + \gamma_{wm} V_m}{q_f + \gamma_{wf} V_f} \tag{27}$$

Scales of force and mass

Thus

$$C_R = C_m = C_l^{\frac{3}{2}} \qquad (28)$$

that is not comparable with (22), however scale of hydrostatic forces

$$C_R = \frac{m_m g - \gamma_{wm} V_m}{m_f g - \gamma_{wf} V_f} = C_l^{\frac{3}{2}} \qquad (29)$$

Then expression (27) should be written down not as scale of forces C_R, and scale of mass C_m, and we shall write down it as

$$C_m = \frac{C_R q_f + \gamma_{wm} C_l^3 V_f}{q_f + \gamma_{wf} V_f} = C_l^3 \left(\frac{C_l^{-\frac{3}{2}} q_f + \gamma_{wm} V_f}{q_f + \gamma_{wf} V_f} \right) \qquad (30)$$

Scales of scale of volumetric weight of the fishing gear

or with the account (23)

$$C_\gamma = \frac{\gamma_m}{\gamma_f} = \frac{C_l^{-\frac{3}{2}} q_f + \gamma_{wm} V_f}{q_f + \gamma_{wf} V_f} \qquad (31)$$

where γ_f - volumetric weight of a material of which the full-scale fishing gear is made; γ_m - volumetric weight of a material of which the model of a fishing gear is made.

Let's note, that $C_\gamma \neq 1$. Expression (31) is necessary for a choice of a material of model of a fishing gear. Expression (31) its right part we shall divide on q_f and

$$C_\gamma = \frac{C_l^{-\frac{3}{2}} + \frac{\gamma_w V_f}{q_f}}{1 + \frac{\gamma_w V_f}{q_f}} = \frac{C_l^{-\frac{3}{2}} + A_f}{1 + A_f} \qquad (32)$$

where $A_f = \gamma_w V_f / q_f$ - the relation of forces.

Scales of scale of volumetric weight of the fishing gear

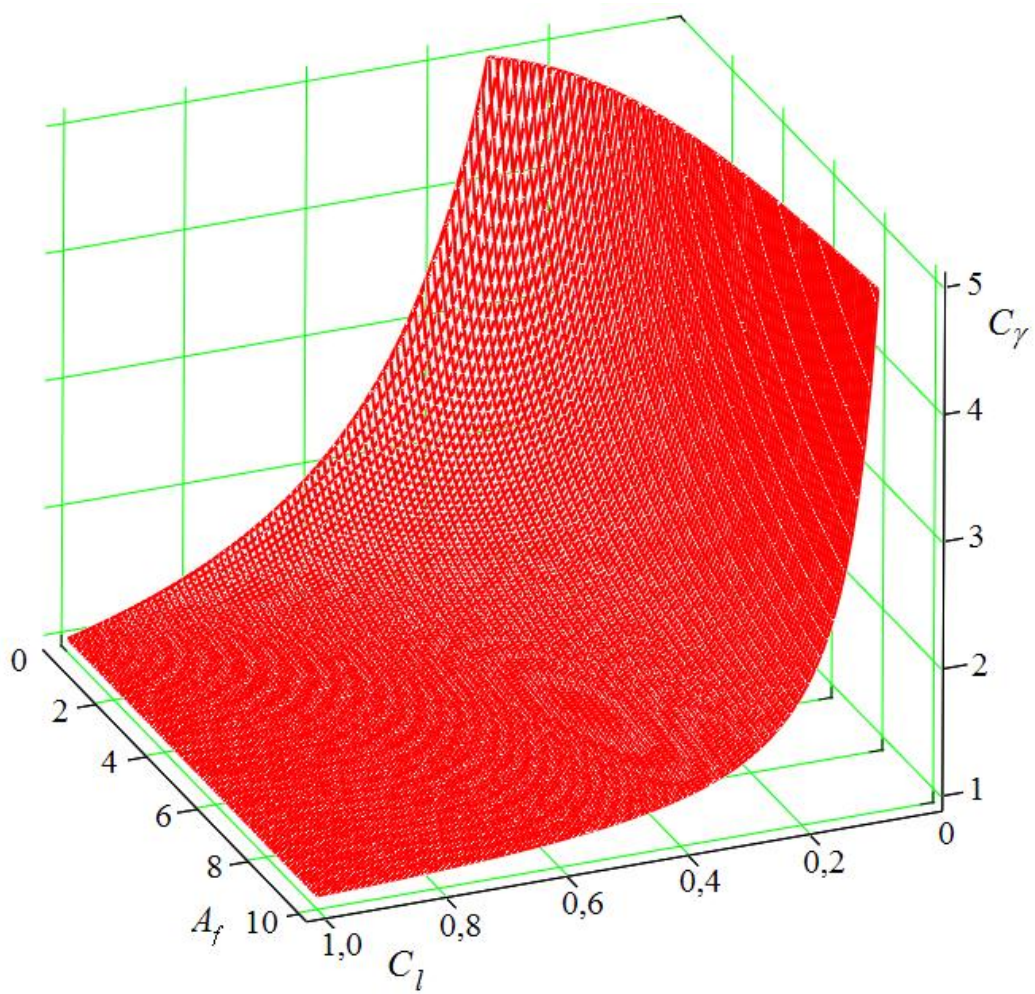


Figure 2
The schedule of three-dimensional dependence $C_\gamma = f(C_l, A_f)$ for $0 \leq C_l \leq 1$ and $0 \leq A_f \leq 10$.

Methodic of carrying out of experiments

For check on adequacy of the resulted rules of dynamic similarity of fishing systems experiences with spheres (see table 1), with models of Danish seine (Nedostup et al., 2010) and model have been carried out. Comparison of the received results is carried out on the basis of mathematical and physical modelling immersing a sphere in a liquid (water) with the account and without taking into account lateral current. Characteristics of a sphere - nature are submitted in table 1. Immersing of spheres without lateral current and in view of lateral current was carried out in a flume tank «МариНПО» (Kaliningrad city) (see table 1 - 5).

Methodic of carrying out of experiments

Table 1 Characteristics of a full-scale sphere

Diameter of a sphere D_f mm	Weight in water q_f N	Mass m_f kg	Volumetric weight of a material γ_f N/m^3	Relation of forces A_f	Material
80	0,058	0,274	10030	45,34	Plastic with lead

Table 2 Scales of modeling

C_l	C_U	C_R	C_t	C_ω	C_m	C_γ
0,5	1,189	0,354	0,42	2,828	0,13	1,039

Methodic of carrying out of experiments

Table 3 Characteristics of a sphere - model

Diameter of a sphere D_m mm	Weight in water q_m N	Mass m_m kg	Volumetric weight of a material γ_m N/m^3	Relation of forces A_m	Material
40	0,021	0,036	10420	16,03	Plastic with lead

Table 4 Experimental data (without taking into account current)

Sphere	Y m	$C_l \cdot Y_f$ m	t s	$C_t \cdot t_f$ s
full-scale	2,12	-	8,5	-
model	1,06	1,06	3,5	3,6

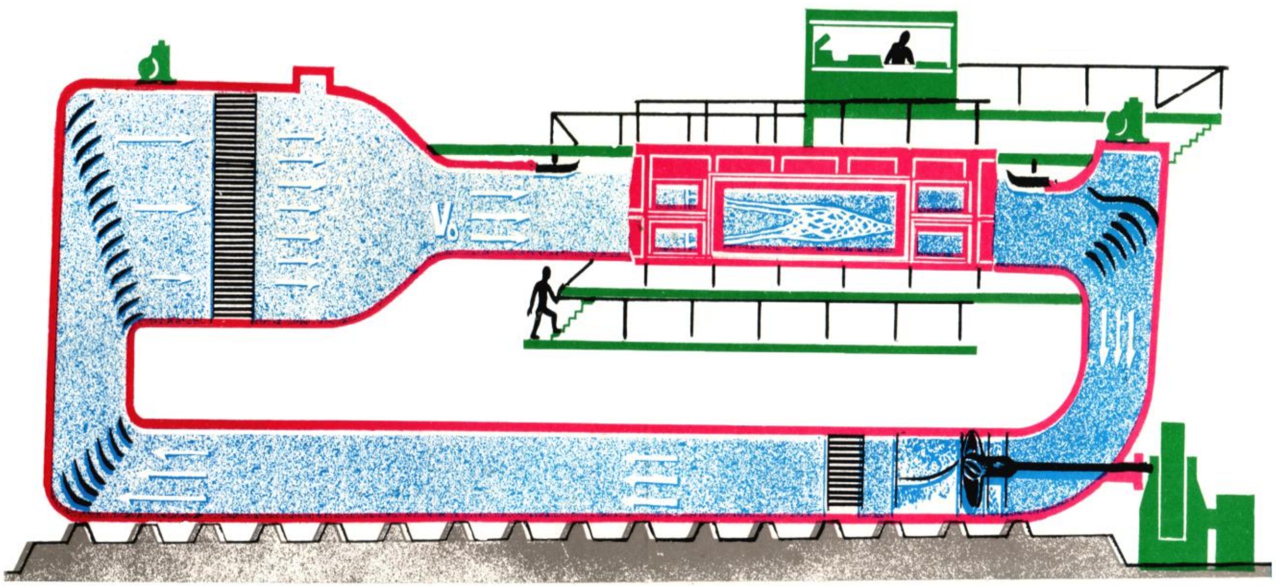
Methodic of carrying out of experiments

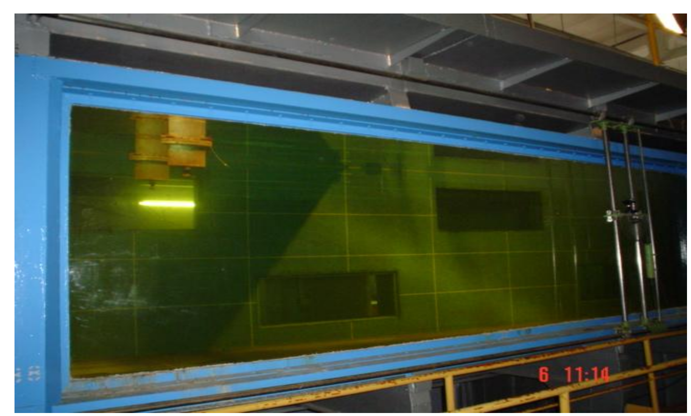
Table 5 Experimental data (in view of current)

Sphere	U m/s	Y m	X m	$C_l \cdot Y_f$ m	$C_l \cdot X_f$ m	t s	$C_t \cdot t_f$ s
full-scale	0,14	2,12	1,18	-	-	10,0	-
model	0,16	1,06	0,6	1,06	0,59	4,1	4,2

The note: *U* - speed of current of water in at flume tank «МариНПО»; *X* - moving on axis OX of a sphere.

Flume tank
"МариНПО" (Kaliningrad, Russia)





Analytical calculations

Proceeding from the equation of dynamics we shall carry out numerical calculations of dependence of depth of immersing (moving) a sphere (see table 1 and 3) from time (see fig. 3 and 6), and speeds of immersing of a sphere from time (see fig. 4 and 7).

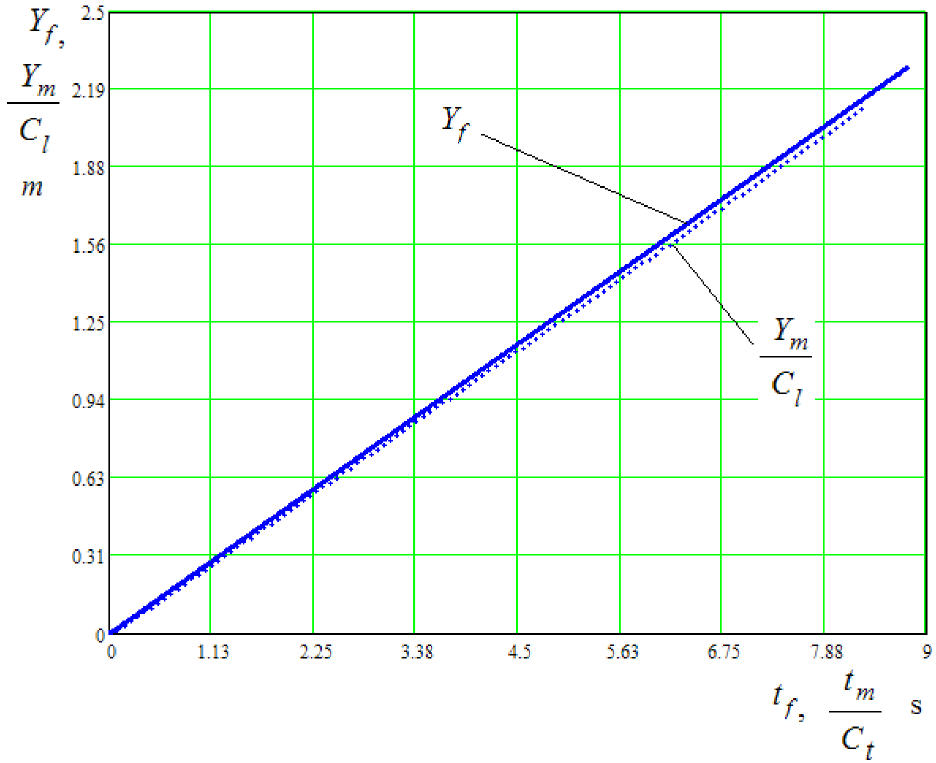


Figure 3
Schedules of dependences Y_f=f(t_f) and Y_m/C_l=f(t_m/C_t) (without lateral current).

Analytical calculations

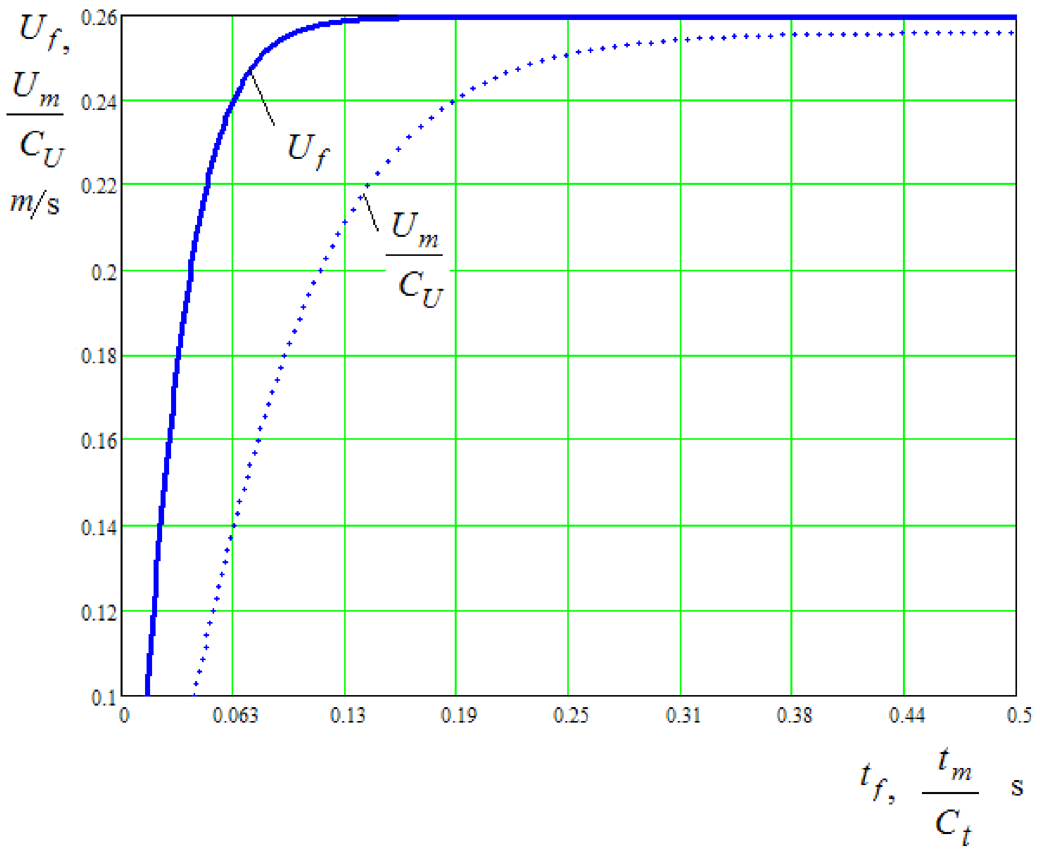


Figure 4
Schedules of dependences U_f=f(t_f) and U_m/C_U=f(t_m/C_t) (without lateral current).

Analytical calculations

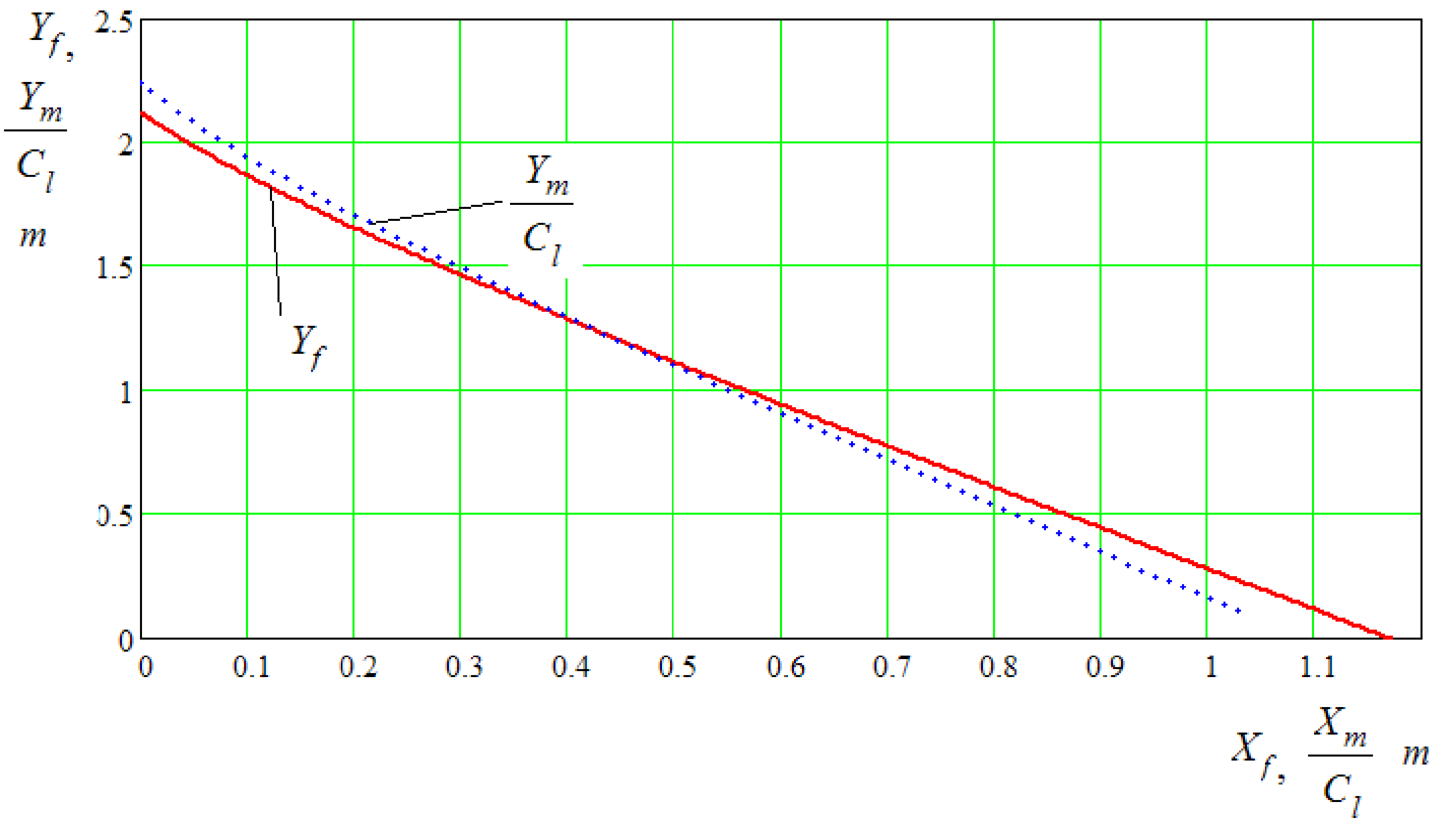


Figure 5

Schedules of dependences Y_f=f(X_f) and Y_m/C_l=f(X_m/C_l) (with lateral current)

Analytical calculations

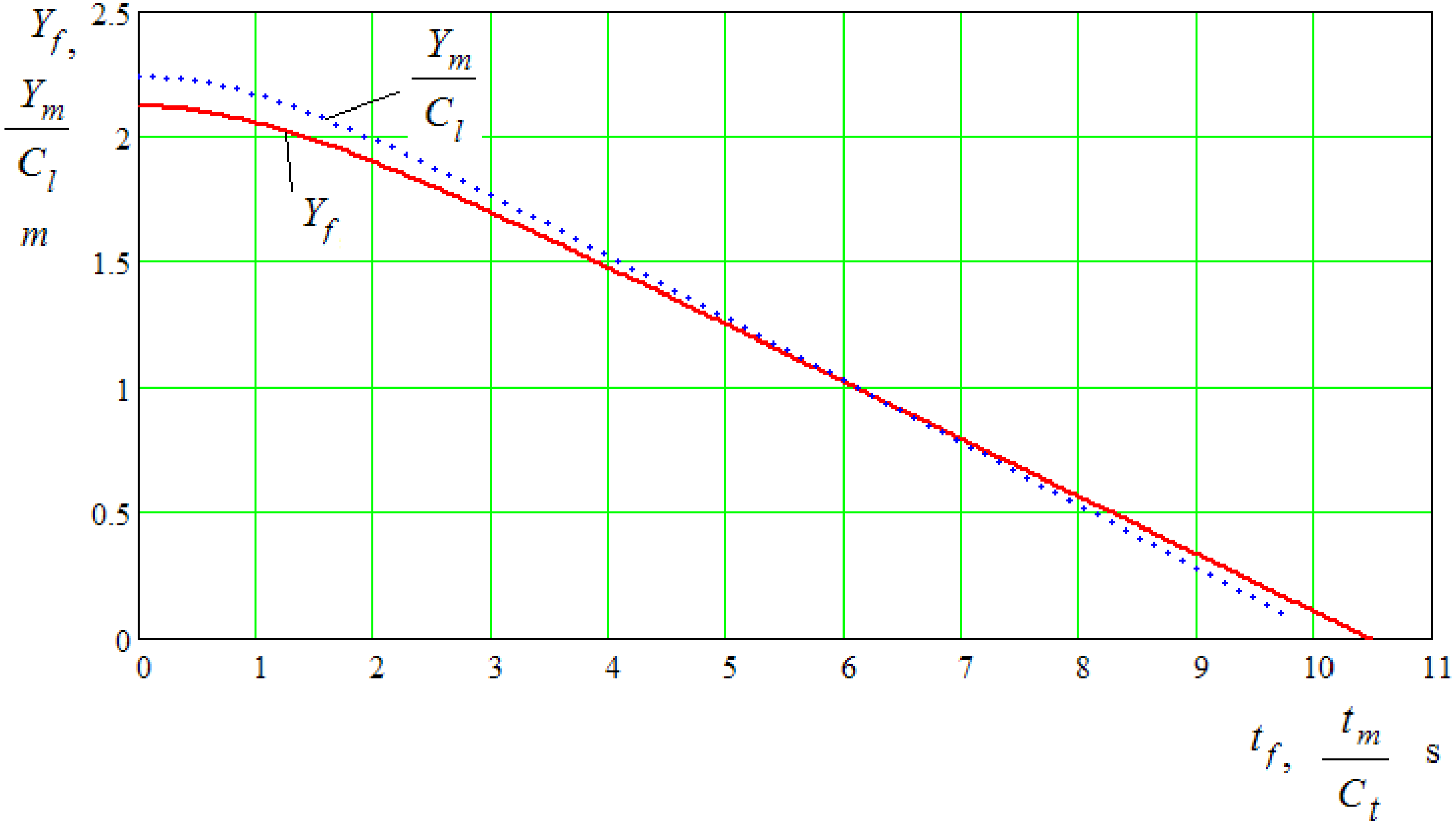


Figure 6

Schedules of dependences Y_f=f(t_f) and Y_m/C_l=f(t_m/C_t) (with lateral current)

Analytical calculations

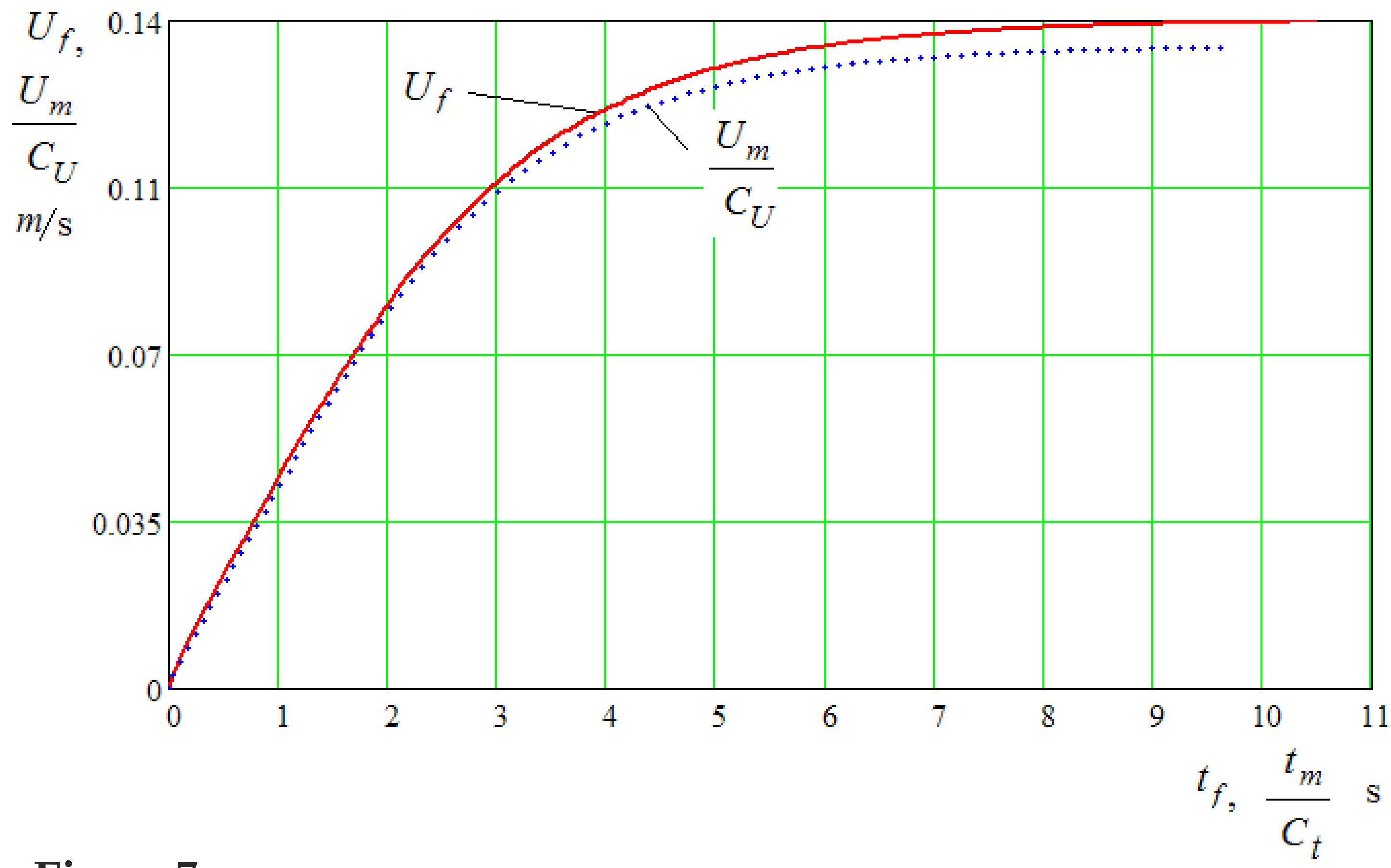


Figure 7

Schedules of dependences U_f=f(t_f) and U_m/C_U=f(t_m/C_t) (with lateral current)

Dynamic coefficient of viscosity liquid (water or etc.)

At mathematical modelling immersing a sphere the formula by definition of coefficient of drag was used

$$c_x = \frac{24}{\mathrm{Re}}\left(1 + 0{,}179\sqrt{\mathrm{Re}} + 0{,}013\mathrm{Re}\right) \quad if \quad \mathrm{Re} \le 1478 \qquad (33)$$

$$\mathrm{Re} = \frac{DU}{\upsilon} \qquad (34)$$

where Re - number of Reynolds; υ - coefficient of kinematic viscosity liquid (water or etc.).

Let's note, that the dynamic coefficient of viscosity of a liquid (water) μ is connected

$$\frac{C_R}{C_l^2} = C_\mu \frac{C_U}{C_l} \qquad (35)$$

where C_μ - scale of dynamic coefficient of viscosity of a liquid,

Dynamic coefficient of viscosity liquid (water or etc.)

$$C_\mu = C_\upsilon C_\rho \quad (36)$$

where C_υ - scale of kinematic coefficient of viscosity of a liquid.
With account $C_\rho \approx 1$ (for water), then for modelling in water

$$C_\mu \approx C_\upsilon \quad (37)$$

With the account (18) - (21), (36) we shall express from (35) scale C_υ

$$C_\mu \approx C_\upsilon = C_l^{\frac{3}{4}} \quad (38)$$

Aknowledgements

Rules of physical modelling (18) - (21) provide modelling dynamic processes of fishing gears. The received results testify to increase in mistakes of physical modelling of dynamic processes in conditions: $0 \leq C_l \leq 1$ and $1 \leq C_l \leq \infty$ under condition of (30), (31) and (38) in water.

Article is prepared within the framework of performance of the grant of the Russian Federal Property Fund № 11-08-00096-a.

Thank you for attention!