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BASIC INVESTIGATIONS ON THE REALIZATION OF AIMED FISHING BY PELAGIC OTTER TRAWLS

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The scientific-technical realization of aimed fishing is an essential precondition for a considerable increase of the efficiency relation between the motions of ship, trawl winch, and trawl, respectively, in required. In the present paper methods for the calculation of ship's and trawl's motions after starting manoeuvres by rudder, propeller, or winches are introduced and selected results are discussed.

INTRODUCTION

In the framework of research in fishing engineering of developed fishing countries extensive projects for the scientific-technical realization of aimed pelagic trawl fishing have been tackled.

Various firms from Western Europe and Japan offer sector-scanning sonars that show the ship's or fishing gear's position (e.g. for purse seines) as well as the distribution of the fish concentration in the vehicle's reach of sight graphically on a display (horizontally and vertically). At the same time ship's course, velocity and other parameters being important for the catch are indicated.

, Devices of this kind give important information for ship's operation forming a basic precondition for aimed fishing. However, experiences in handling those devices showed that though the detection of fish concentrations has been improved due to the very good location technology, low draughts of fish are nevertheless often to be noticed.

The explanation for this lies in the fact that the net is moved by suitable ship's manoeuvres to a given target area. Because of the complexity of the preorientation in four-dimensional space with the 3 axes of the geometrical space and a time axis man is only in very simple cases able to make for a fish concentration after having aimed at it.

In the GDR for several years investigations have been carried out within the framework of the complex of research work "Automized fishing system" related to the above-mentioned probleIU.--

These investigations aim at the gradual preparation of a microcomputer-controlled fishing system that is meant to automize the operations heaving and veering of the trawl warp during net-hauling and laying-out of the net as wewell as vertical and horizontal trawl steering applying the above-mentioned location technology.

A basic precondition for the use of microcomputers on board of fishing ships is apart from the development of a suitable hardware also the supply of the necessary software as logarithms for the solution of the most different tasks as e.g.:

- optimum heaving and veering speed during hauling and layingout of the trawl;
- calculation of appropriate ship's and winch manoeuvres for the successful approach and fishing of fish concentrations by the trawl;
- storage of other located fish concentrations in order to make it possible to find them after some time;
- control of propeller pitch and heaving and veering speed under the point of view of the power being available;
- functions of anticollision and average control a.s.f.

For the fundamental investigations it is unimportant, whether a central shipboard calculator or decentralized calculation units are applied.

In the present paper algorithms are shown for investigating the correlations between the trawler's and the trawl net's motion. They form the basis for the determination of the manoeuvres in advance that are necessary for aimed fishing.

Results are presented and discussed.

CRITERIA FOR CREATING A SUITABLE MODEL

Making available a suitable algorithm for the calculation of the ship's and trawl's processes of motion a compromise has to be made between the usable hard- and software on the one hand and the degree of automation including the requirements of accuracy on the other hand.

A shipboard calculator should fulfil the requirement that it initiates corresponding manoeuvres just immediately after the location of a fish concentration, so that the trawl approaches the fish school and comes in the position to fish off. That is the reason why the development of more simple, sufficiently accurate models is necessary for the special use on board (Paschen a. Lindenberg, 1981; Paschen, 1983).

As it is usually the case theoretical results are to be determined experimentally as well. Today in our particular case it is only possible with restrictions for special cases using smaller models.

For special investigations system models have been developed in order to determine the motion behaviour of important partial systems as e.g. ship, trawl winch, towing warp, otter board and net, for which a possibly high degree of approximation to real conditions should be reached, so that in this way further results are available to be used for comparison.

In the following chapters an extensive system model and a strongly simplified model for calculating the ship's and trawl's paths of motion are introduced and described mathematically. Subsequently the performance of the simple calculation method is checked using for this the results of the numerical calculation.

DESCRIPTION OF THE SYSTEM MODEL SHIP - TRAWL

Physical simulation

The qualitatively right reproduction of the motion behaviour of the real fish catching system in a high degree depends on the fact, to what extent the relevant forces and geometrical relations of the model correspond to those of the original. A model of the catching system that satisfies this criterion has been developed (Fig. 1) in order to solve the task that has been set.

The ship's motion takes place in three degrees of freedom at the smooth surface of an infinitesumally extended, incompressible, homogeneous fluid that is cahn in infinity.

Pitching and heeling angle as well as draught are supposed to be constant for the whole process of moti :m. The wind forces acting on the ship are not taken into account.

The forces and moments acting on the underwater hull of ship are supposed to be known and may be described mathematically.

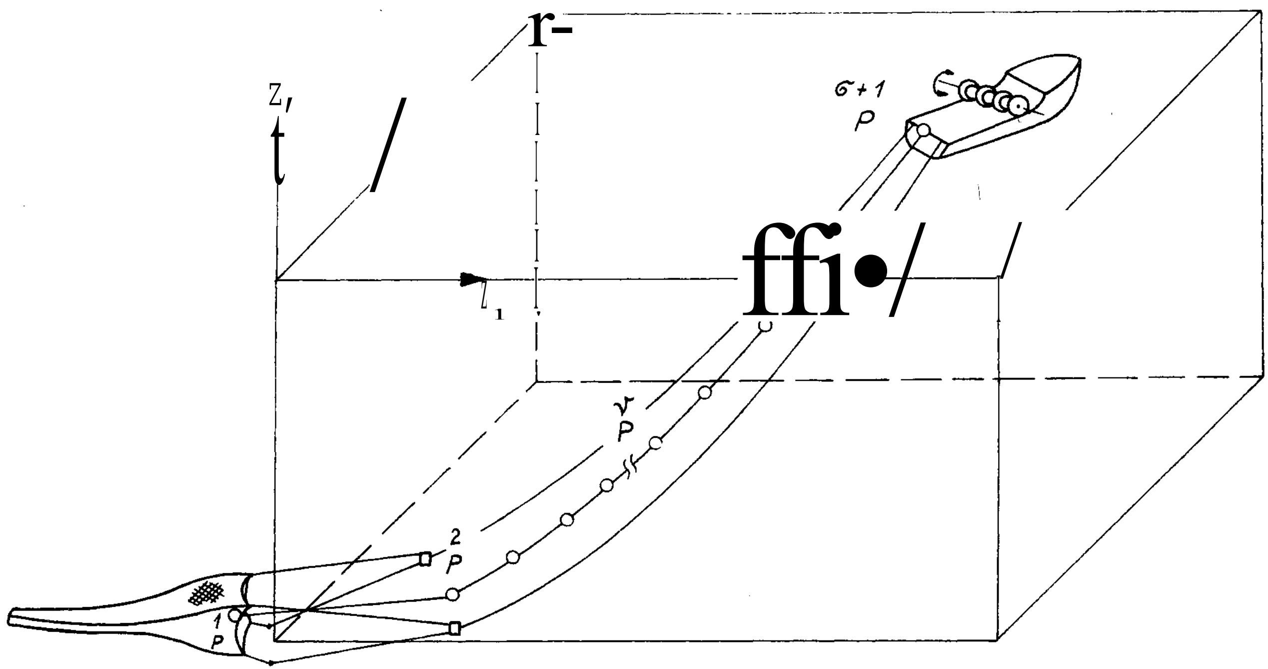
The model of the fishing appendages consists o a substitute trawl warp, a punctiform substitute otter board, a substitute cable and a trawl pocket - concentrated in one point, including trawl rigging and catch.

It carries out motions in the interior of the defined fluid in three-dimensional space.

The towing warp is considered an ideally flexible, nonstretchable, rod-shaped chain with point masses.

It is diverted over the topping block that is projected into the ship's centre-line plane to the trawl winch.

On the otter board and on the net forces of tension and forces of mass and a hydrodynamic force are acting in negative direction of the corresponding vector of velocity. It is taken as a basis that the real net always hangs in the current's direction.



Model of a pelagic single ship trawl system

Mathematical bases

The basis of the calculation method is formed by the equations of motion of the constituents belonging to the whole system and mainly affecting its motion behaviour. They may be obtained by the application of the fundamental law of mechanics.

The ship's motion is according to the agreement carried out as translation in z1 - z2 direction of the space-fixed coordinate system and rotation around the vertical axis (Fig. 2).

For the represP.ntation of the flow around the ship the body-fixed x1 - coordinate system (with i = 1,... 3) is preferred. Its origin lies in the centre of gravity formed by ship's mass and hydrodynamical mass, –

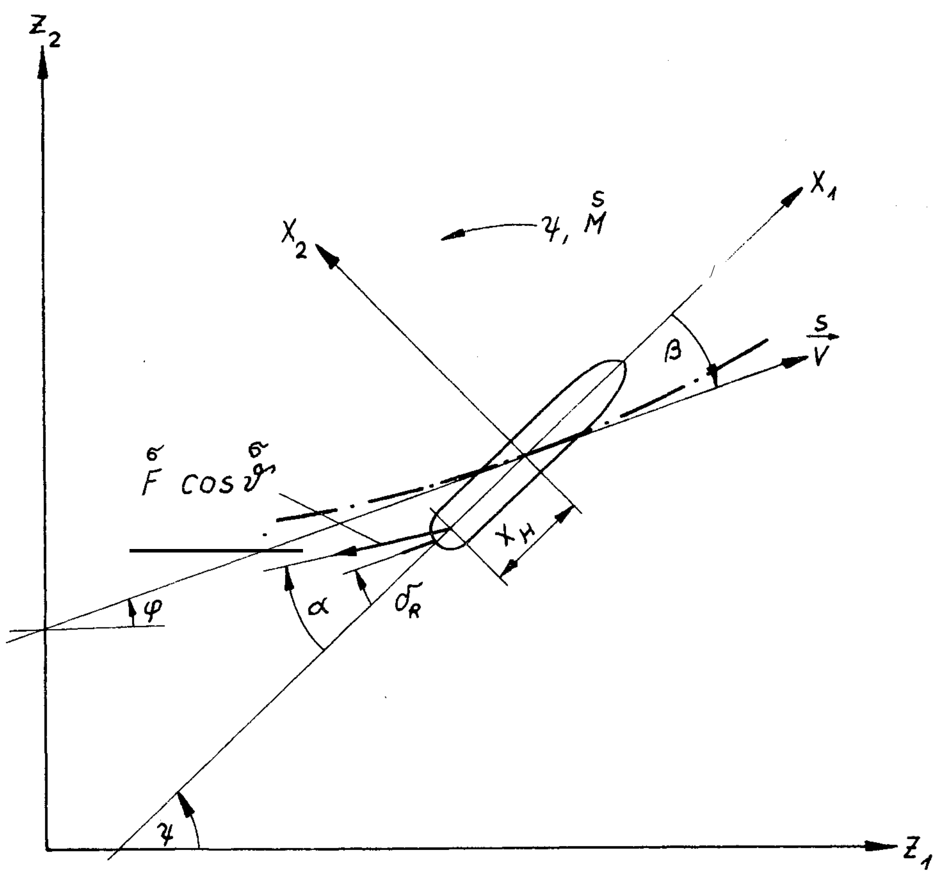


Fig. 2 Coordinate systems and g.uantities for the description of the ship's motion

With respect to a tensile force acting at the ship's stern as a consequence of the catching ship's motion the equations of motion are obtained according to SCHMITZ (Schmitz, 1961).

$$(\overset{s}{m} + \overset{s}{m}_{h1})(\dot{\overset{s}{v}}\cos\beta - \overset{s}{v}\dot{\beta}\sin\beta) + (\overset{s}{m} + \overset{s}{m}_{h2})\,\dot{\psi}\,\overset{s}{v}\sin\beta = \overset{s}{F}_1 - \overset{\sigma}{F}\cos\alpha\cos\overset{\sigma}{\vartheta} \quad (1.1)$$

$$-(\overset{s}{m} + \overset{s}{m}_{h2})(\dot{\overset{s}{v}}\sin\beta + \overset{s}{v}\dot{\beta}\cos\beta) + (\overset{s}{m} + \overset{s}{m}_{h1})\,\dot{\psi}\,\overset{s}{v}\cos\beta \quad (1.2)$$

$$\overset{s}{F}_2 + \overset{s}{F}\sin\alpha\cos\alpha\,\overset{\sigma}{\vartheta}$$

$$(\overset{s}{J}_3 + \overset{s}{J}_{h3})\,\ddot{\psi} = \overset{s}{M}_3 - \overset{\sigma}{F}\sin\alpha\cos\overset{\sigma}{\vartheta}\,x_H \quad (1.3)$$

On the left sides of the equations the terms of inertia of ship's mass and fluid's mass are to be found – on the right sides the forces and moments acting due to flow around ship and due to motion.

The hydrodynamic load acting on the ship's hull depends on the ship's form and the ship's position with respect to water plane as well as on the following parameters: yawing angle, rudder deflection, curvature of path, thrust load coefficient of propeller, velocity, Reynolds and Froude number.

The experimental determination of the hydrodynamic forces and moments using ship's models doesn't cause any difficulties.

The solution of the equations of motion for the fishing appendage provide the tensile force of rope $\overset{\sigma}{F}$ as well as the slope and diverging angle of rope $\overset{\sigma}{\vartheta}$ and α, so that using the set of equations (1) β, v and ψ may be determined by numerical integration.

For the mathematical presentation of the fishing appendage's motion the towing warp is subdivided in an arbitrary number of segments of any length.

In the centre of each segment the mass of this segment is to be found that is concentrated in one point where forces of inertia, weight and tension and hydrodynamic forces are acting (Fig. 3).

The hydrodynamic load of the ν-th segment of warps is obtained after summation of the forces that are calculated with regard to the position of the lower and upper and relative to flow. In this way the whole fishing appendage seems to be a mathematical multiple pendulum being able to vibrate in three-dimensional space, whereas its vibrations are damped in the points $\overset{1}{P}$ to $\overset{\sigma}{P}$ due to directional hydrodynamic forces.

It is set up that with the exponential indices

$\nu = 1$ the net

$\nu = 2$ the substitute otter board and

$3 \leqq \nu \leqq \sigma$ the towing warp's segments are designated.

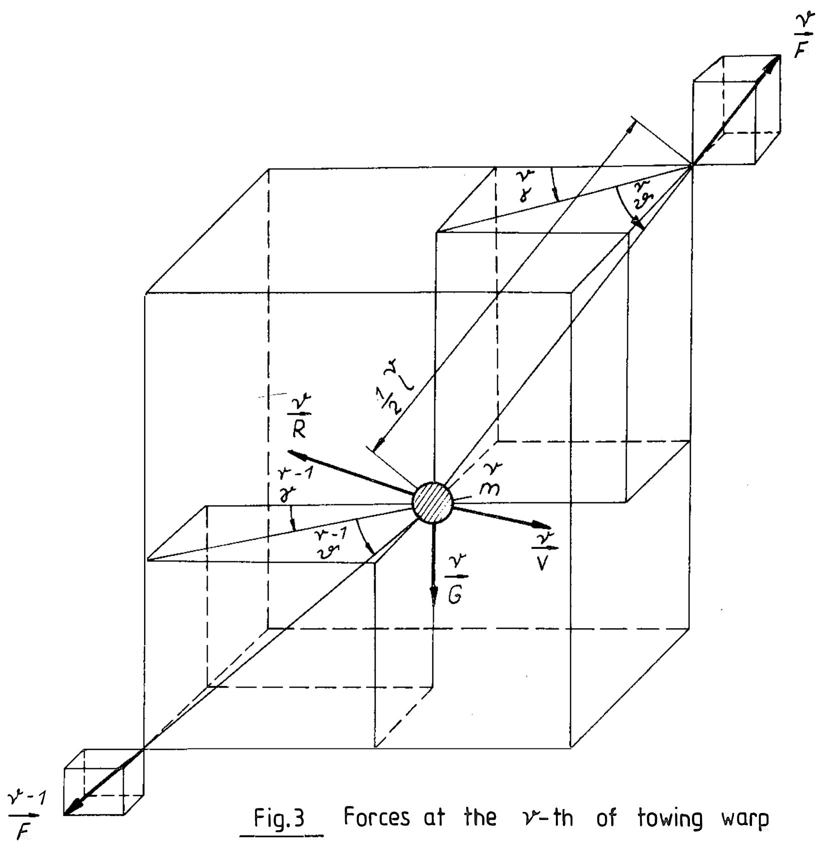


Fig.3 Forces at the ν-th of towing warp

The rope can only take up tensile forces along its tangent, so that the direction of the ν-th tensile force of rope $\overset{\nu}{\mathrm{F}}$ is given only by the tangential vector of rope $\overset{\nu}{\vec{\mathrm{f}}}$.

$$\overset{\nu}{\vec{\mathrm{f}}} = \frac{1}{|\overset{\nu}{\vec{\mathrm{F}}}|}\,\overset{\nu}{\vec{\mathrm{F}}} \left\| \begin{matrix} \cos\overset{\nu}{\vartheta}\cos\overset{\nu}{\gamma} \\ \cos\overset{\nu}{\vartheta}\sin\overset{\nu}{\gamma} \\ \sin\overset{\nu}{\vartheta} \end{matrix} \right\| \qquad (2)$$

$\overset{\nu}{\vec{\mathrm{f}}}$ always lies on the straight connection of two adjacent mass points $\overset{\nu}{\mathrm{P}}$ and $\overset{\mu}{\mathrm{P}}$. ($\mu = \nu+1$) and is in the point's direction defined as being positive, so that the position of these points may be described in the following way

$$\overset{\mu}{\vec{\mathrm{r}}} = \overset{\nu}{\vec{\mathrm{f}}} + \frac{1}{2}(\overset{\mu}{\mathrm{l}} + \overset{\nu}{\mathrm{l}})\,\overset{\nu}{\vec{\mathrm{f}}} \qquad (3)$$

For the mass points are always lying in the centre of their segments, the derivatives are obtained

$$\dot{\vec{v}}^{\mu} = \dot{\vec{v}} + \frac{1}{2} \left[(\overset{\mu}{l} + \overset{\nu}{l})^{\cdot} \overset{\nu}{\vec{f}} + (\overset{\mu}{l} + \overset{\nu}{l}) \dot{\overset{\nu}{\vec{f}}} \right] \tag{4}$$

and

$$\ddot{\vec{v}}^{\mu} = \ddot{\overset{\nu}{\vec{v}}} + \frac{1}{2} \left[(\overset{\mu}{l} + \overset{\nu}{l})^{\cdot\cdot} \overset{\nu}{\vec{f}} + 2 (\overset{\mu}{l} + \overset{\nu}{l})^{\cdot} \dot{\overset{\nu}{\vec{f}}} + (\overset{\mu}{l} + \overset{\nu}{l}) \ddot{\overset{\nu}{\vec{f}}} \right] \tag{5}$$

Its is useful to simulate heaving adn veering processes by a simultaneous variation of length of the upper and lower branch of the towing warp's segmentσ. We have

$$(\overset{\mu}{l} + \overset{\nu}{l})^{\cdot} = (\delta_{\sigma\mu} + \delta_{\sigma\nu}) \dot{l} \tag{6}$$

and

$$(\overset{\mu}{l} + \overset{\nu}{l})^{\cdot\cdot} = (\delta_{\sigma\mu} + \delta_{\sigma\nu}) \ddot{l} \tag{7}$$

Here the following is of general validity

$$\delta_{ij} = \begin{cases} 1 & \text{für} \quad i = j \\ 0 & \text{für} \quad i \neq j \end{cases}$$

The heaving or veering speed $\dot{l}$, respectively, as well as the heaving or veering acceleration of trawl warp l result from the motion behaviour of the towing winch.

The equilibrium of forces for the point $\overset{\nu}{P}$, related to the three dimensional coordinate system z_i (i = 1...3) provides according to fig. 3.

$$\overset{\nu}{\vec{T}} = \overset{\nu}{\vec{F}} - \overset{\nu-1}{\vec{F}} + \overset{\nu}{\vec{R}} + \overset{\nu}{\vec{G}} \tag{8}$$

here $\overset{\nu}{\vec{T}} = \overset{\nu}{m} \cdot \dot{\overset{\nu}{\vec{v}}}$ represents the vector of the force of inertia, $\overset{\nu}{\vec{F}}$ is the upper and $\overset{\nu-1}{\vec{F}}$ the lower vector of the tensile force of rope, $\overset{\nu}{\vec{R}}$ – the vector of the hydrodynamic load and $\overset{\nu}{\vec{G}}$ – the vector of weight (weight in water).

Equation (8) is generally valid for each segment $2 \leqslant \nu \leqslant \sigma$. For the special case $\nu = 1$ the vector of tensile force of rope $\overset{\nu-1}{\vec{F}}$ diaappears.

The hydrodynamic load $\overset{\nu}{\vec{R}}$ is generally determined using the following set-up

$$\overset{\nu}{\vec{R}} = \|\overset{\nu}{R}_i\| = \frac{1}{2}\rho(\overset{\nu}{\vartheta})^2 \overset{\nu}{A} \|\overset{\nu}{C}\| \qquad (9)$$

here $\|\overset{\nu}{c}_i\|$ is the vector of experimentally determined directional hydrodynamic coefficients. We do without determining them more in detail (see Paschen, 1981).

Now if the derived equations (2), (4), (5), and (9) are substituted into the equation of forces (8), and arranged in an order, then the quantities $\overset{\nu}{\ddot{\gamma}}$ and $\overset{\nu}{\dot{\vartheta}}$ as well as $\overset{\nu}{\vec{F}}$ with $1 \leqslant \nu \leqslant \sigma$ that are required for determining the motion of the fishing appendage, may be determined in dependence on the ship's motion and the characteristic of winches and fishing gear.

The solution of the derivatives of $\overset{\nu}{\gamma}$ and $\overset{\nu}{\vartheta}$ is possible without any difficulties using numerical methods (e.g. method by Runge-Kutta).

A MODEL FOR THE SYSTEM SHIP – FISHING GEAR AFTER STRONG SIMPLIFICATION WITH RESPECT TO ITS APPLICABILITY ABOARD SHIP

Physical simulation

Calculating the manoeuvres of ship and winches being necessary for the aimed approach of fish schools on board of fishing vessels requires very simple solution algorithms, because numerical methods are much too time-consuming. Another fact is that making available the necessary manipulated variables for the control of ship and winches as fast as possible at a low computer capacity has to take place excluding the use of large computer systems.

The basis for deriving physically sensible solution set-ups can only be equations of motion that result from strongly simplified physical simulations of the systems.

In the following such system model is described for the vertical controlled approach of fish schools:

With one degree of freedom the fishing vessel moves at the surface of a homogeneous, incompressible fluid being calm in infinity. Effects of wind and waves as well as heeling and trim position of the ship and also the effect of the pressure field, that is to built up resulting from the hull's and the propeller's motion, on the net appendage are all neglected.

Under the condition of a straight ship's course, same lengths of trawl warps, different-handed ropes and the same otter boards a symmetry of fishing gear is to be noticed related to the extended ship's longitudinal axis. Thus trawl warps may be combined to a substitute trawl warp, which has the properties of an infinitesimal thin rope in flow. The net including rigging as well as otter boards as a whole may be regarded as an obstacle that unites the properties of these partial systems in itself with regard to weight load and hydrodynamic load and is located at the end of the substitute trawl warp (Fig. 4). It is further supposed that the changes of trawl depth being necessary in the

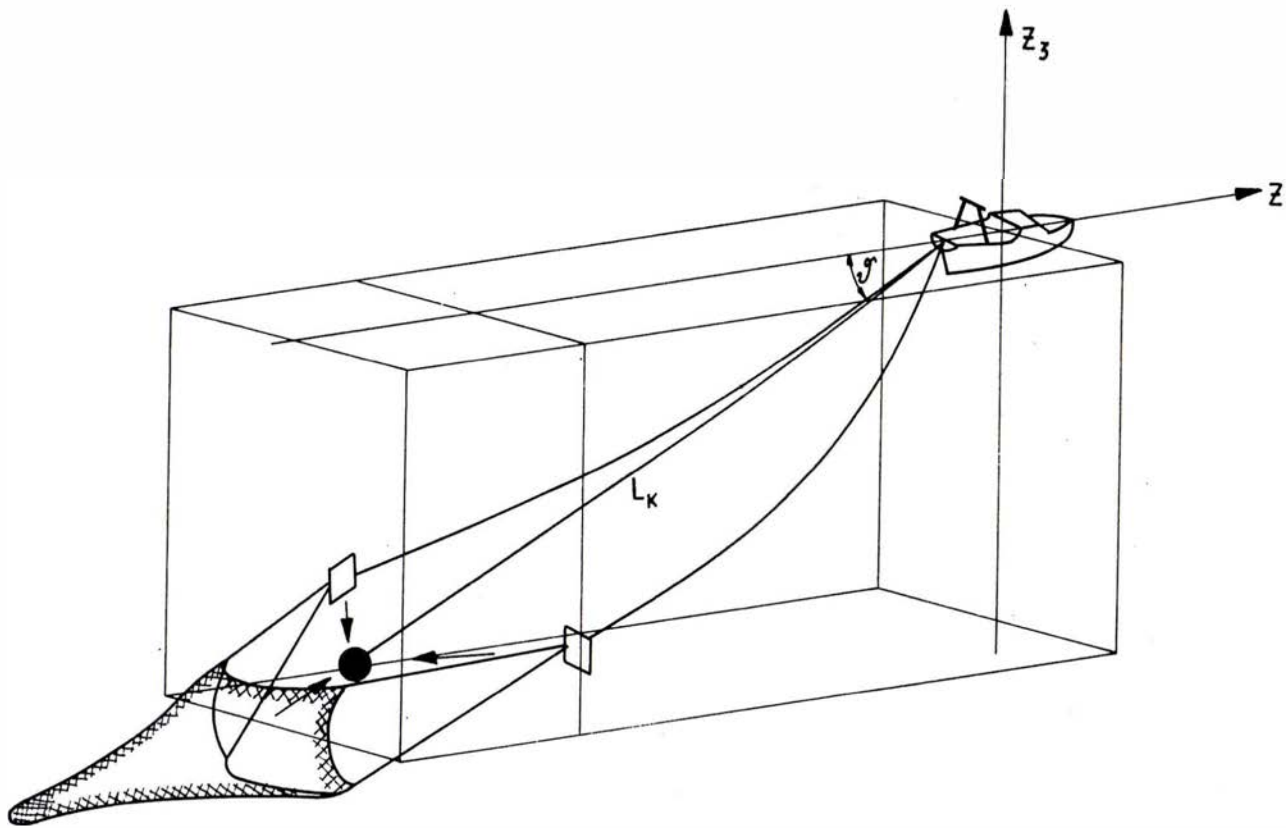


Fig. 4 Presentation of the net appendage as a two-dimensional single pendulum

vertical process of approaching the fish schools are small compared to trawl depth itself, so that the changes in the rope length occurring due to winch manoeuvres compared to total rope length may be neglected while calculating the slope and diverging angle of warp.

Mathematical simulation

For the changes of trawl depth are very slow due to propeller and winch manoeuvres and the accelerations are small, the forces of inertia of the net appendage may be neglected in first approximation in comparison to hydrodynamic and weight loads. So from the correlations of moments at the point of launching the substitute trawl warp from the fishing vessel's stern the following relation may be obtained.

$$O = R_{z1} L_k \sin\vartheta - (G_N + 2G_{sB} - R_{z3}) L_k \cos\vartheta \qquad (1)$$

Assuming that the resultant of hydrodynamic force always acts in the inflow's direction, its components may be described in the following way:

$$R_{Z1} = \frac{\rho}{2} (C_N A_N + 2c_{sB} A_{sB}) V_N V_{NZ1}$$

$$R_{Z3} = \frac{\rho}{2} (C_N A_N + 2C_{sB} A_{sB}) V_N V_{NZ3} \qquad (2)$$

The velocity components of the net appendage correspond to the derivatives of its coordinates with respect to time

$$Z_{1N} = Z_{1S} - L_K(t) \cos\vartheta \qquad V_{NZ1} = V_S + \dot{\vartheta} L_K(t) \sin\vartheta + V_H \cos\vartheta$$

$$Z_{3N} = -l_K(t) \sin\vartheta \qquad V_{NZ3} = -\dot{\vartheta} L_K(t) \cos\vartheta + V_H \sin\vartheta \qquad (3)$$

with
$$V_H = -\frac{dL_K}{dt}$$

After having substituted relations (2) and (3) into equation (1) and subsequent simplification the following relation may be obtained

$$\frac{G_N + 2G_{sB}}{\frac{\rho}{2} (C_N A_N + 2c_{SB} A_{SB}) V_N V_S} = \tan\vartheta + \frac{L_K}{V_S \cos\vartheta} \dot{\vartheta} \qquad (4)$$

Supposing that the resultant of the net's velocity in its value may be equated to the stationary value and that the dynamics of the process has only influences on the instantaneous direction of inflow to the net, then this resultant may be presented as a function of ship's speed, heaving speed and of the slope angle. In this way an inhomogeneous non-linear differential equation of first order has been found for the description of the unstationary motion of the net appendage

$$\dot{\vartheta} = f(\vartheta, V_S, V_H, \text{Konstanten}) \tag{5}$$

From the equilibrium of forces in unstationary motion for the partial system 'ship' the following relation may be derived

$$(m_s + m_{h1})\dot{v}_s = S - F_{Z1} \tag{6}$$

Introducing an empirical set-up for the calculation of rope pull as a function of propeller pitch and ship's speed as well as the approximative determination of the horizontal component of the resultant drag of fishing gear in dependence on ship's and heaving speed the relation (6) may be presented in the following form. It must be added that the empirical set-up has been found in measuring runs for each corresponding type of ship.

$$\dot{V}_S = f(V_S, P/D, V_H, \text{Konstanten}) \tag{7}$$

In order to lead the equations of motion for ship and net appendage to an analytical solution, basing on the initial conditions a linearization with respect to the important influencing quantities is required

$$\dot{V}_S \approx \dot{V}_{SO} + \frac{\partial \dot{V}_S}{\partial V_S}\Big/_0 \Delta V_S + \frac{\partial \dot{V}_S}{\partial P/D}\Big/_0 \Delta P/D + \frac{\partial \dot{V}_S}{\partial V_H}\Big/_0 \Delta V_H \tag{8}$$

$$\dot{\vartheta} \approx \dot{\vartheta}_0 + \frac{\partial \dot{\vartheta}}{\partial \vartheta}\Big/_0 \Delta \vartheta + \frac{\partial \dot{\vartheta}}{\partial V_S}\Big/_0 \Delta V_S + \frac{\partial \dot{\vartheta}}{\partial V_H}\Big/_0 \Delta V_H$$

The solution of the differential equations linearized by a series expansion provides simple set-ups for calculating ship's speed and the slope angle depending on the time after having started the manoeuvre.

$$V_S = V_{SE} + C_{11} e^{\lambda_1 t}$$

$$\vartheta = \vartheta_E + C_{21} e^{\lambda_1 t} + C_{22} e^{\lambda_2 t} \tag{9}$$

Here the constants c_{ij} may be determined from the instantaneous initial conditions. Using equations (9) it is now possible to determine the coordinates of net appendage as well as their derivatives as functions of the time after having started the manoeuvre.

REPRESENTATION AND DISCUSSION OF SELECTED RESULTS

In the following the question should be answered, to what extent the simple solution set-ups derived in the preceding chapter are able to give a qualitatively and quantitatively right description of the real changes of net depth.

Here according to the standard of knowledge gained so far it is assumed that the above-described simulation of the system 'ship – fishing gear' as multiple pendulum according to (Paschen, 1981) shows the real path of the net with sufficient accuracy. A pendulum model with three mass points substitute trawl warp, substitute otter board and net, that has been developed in (Wagner, 1983) on the same basis, is also taken as a comparative model.

Furthermore using the paths of motion of net appendage that have been calculated by means of given rudder, propeller and winch manoeuvres, statements can be made on the field of application of the system model described in chapter 3.

In fig. 5 the comparison of the time-depending variation of ship's speed, tensile force of trawl warp and net depth according to (Wagner, 1983) and according to the analytical solution algorithm is shown. Here it is obvious that during propeller manoeuvres the net's reaction can be shown, too, for unstationary initial conditions with sufficient accuracy.

The correspondence of the net path curves, being sufficient for practical purposes, resulting from increase or decrease of pushing, respectively, for stationary initial condition of the system 'ship – trawl' is also demonstrated figs. 6 and 7.

It can be stated that by means of the time constants λ_i of the analytical solution the real transition behaviour of the net appendage to the new stationary net depth may be

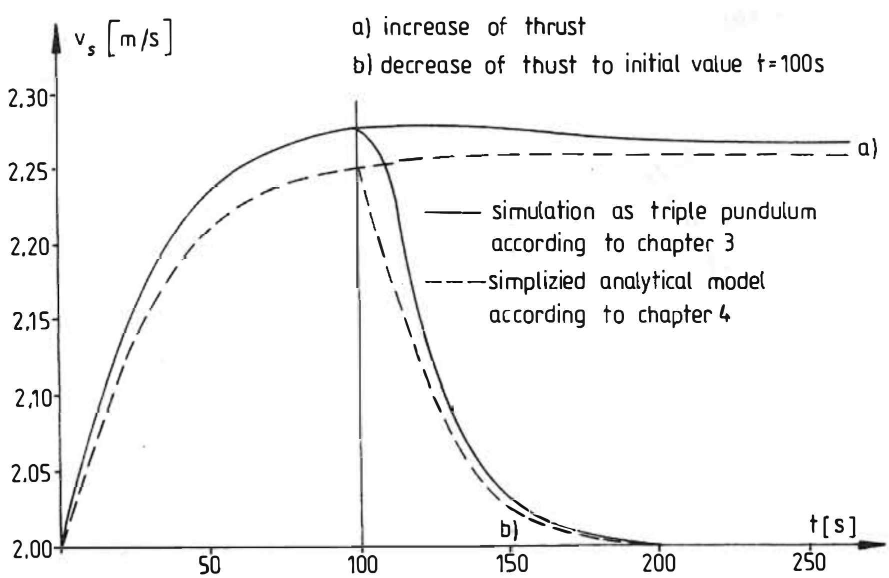


Fig. 5.1 Behaviour of ship's speed due to propeller manoeuvre

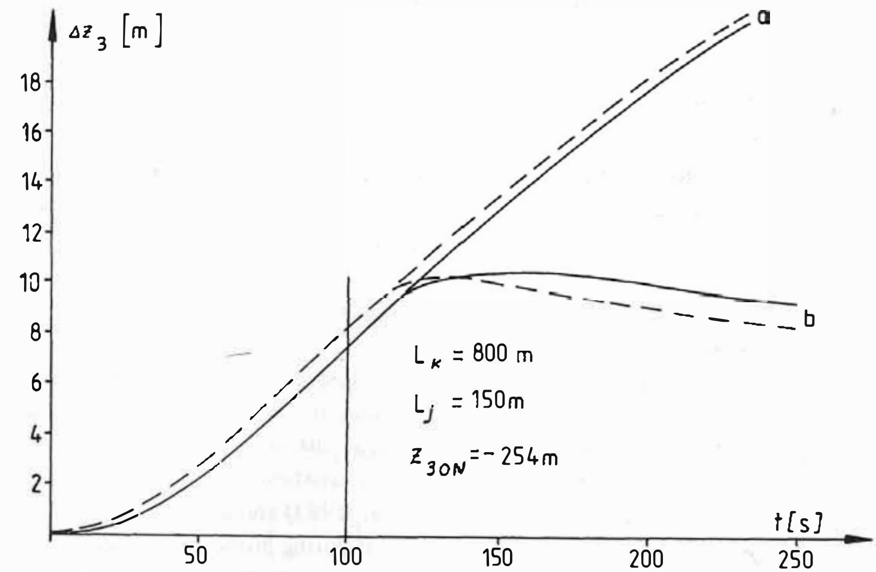


Fig. 5.2 Changes of net depth

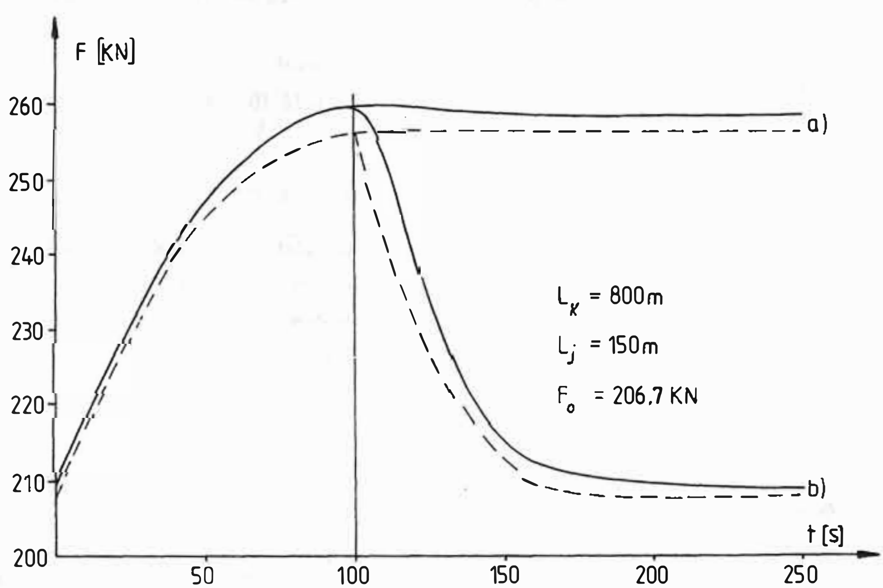


Fig.5.3 Variation of tensile force of trawl warp

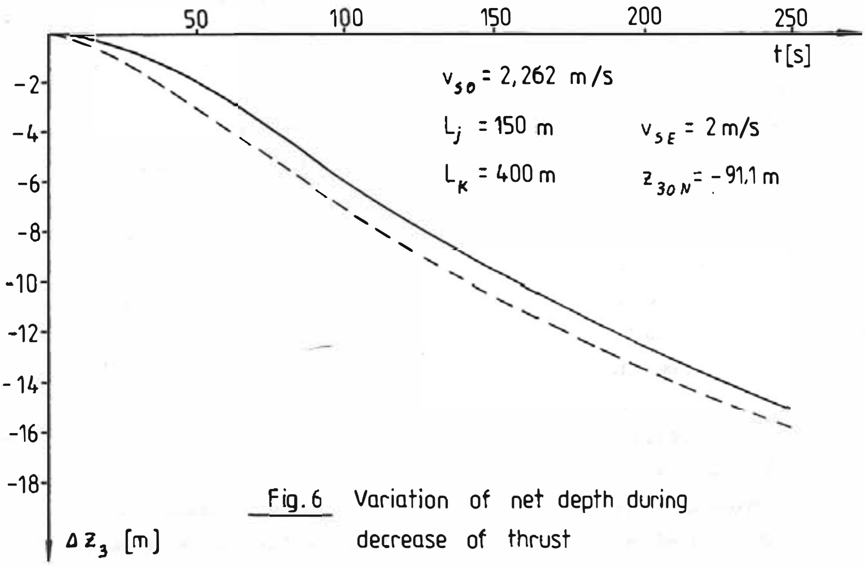


Fig. 6 Variation of net depth during decrease of thrust

described sufficiently accurate. This has also been confirmed by the evaluation of measuring runs with a model net to a scale of 1:16, that have been carried out in the test station INSKO of the

Academy of Agriculture Szczecin at the Insko – lake in October 1982 (after the whole test programme has been finished it is planned to work out a special publication).

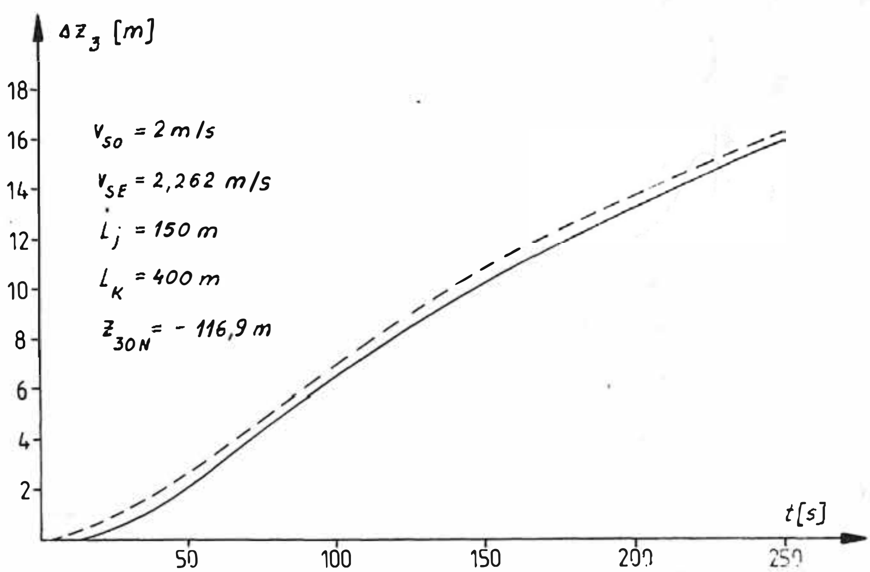


Fig. 7 Variation of net depth during increase of thrust

However, another precondition for the analytical precalculation is also the sufficiently accurate prediction of the stationary final depth of net. For small total changes of net depth related to the initial value in the differences a good correspondence between the two considered models may be realized (Figs. 5—7).

In reality, however, those speed-depending factors as otter board position, shape and in this way drag coefficients of fishing gear as well as changes in deep current have a great influence on the stationary fishing depth of the net. Those changes in fishing gear's geometry, that can't be predetermined under conditions aboard ship, as well as environmental factors, that can't be taken into account, necessarily lead to mistakes in the precalculation of manoeuvres. Therefore an algorithm must be developed that makes a correction of the net path by a corresponding manoeuvre calculation and subsequent realization possible in case that too large deviations between real and calculated net path or in case that the change of position of the fish school concentration occur.

In fig. 8 the degree of correspondence of the simplified solution set-up with a multiple pendulum model for a winch manoeuvre at constant, propeller blade inclination and constant rotary number of propeller is shown. During the heaving manoeuvre ship's speed decreases due to increased net drag. Therefore according to both of the model variants in case of the winch being stopped a "sagging" of the net appendage is to be noticed. The subsequent rise of ship's speed to its initial value is then followed by a decrease of net depth until a new state of equilibrium is reached. It is obvious that by means of the simplified method of solution for the calculation of the net's fishing depth these paths of net motions can at least be shown qualitatively right.

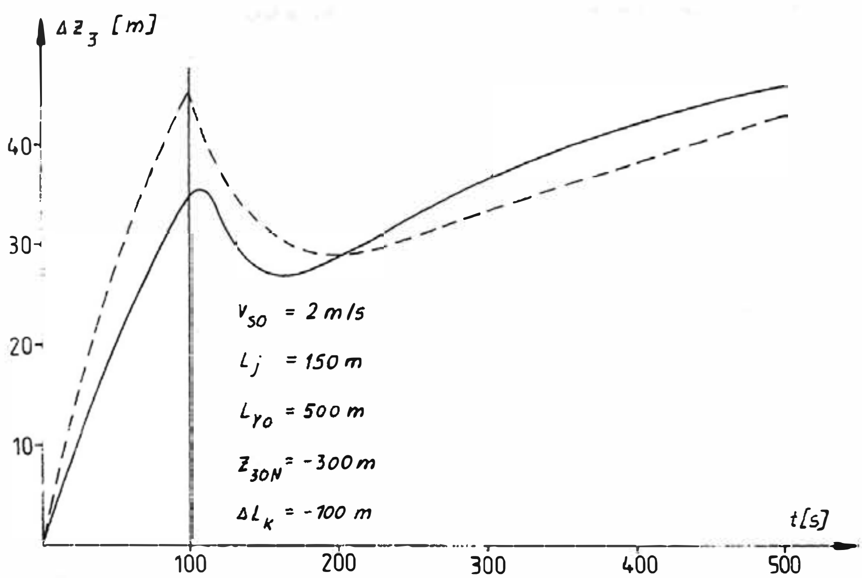


Fig.8 Variation of net depth due to heaving manoeuvre (v_H=1m/s)

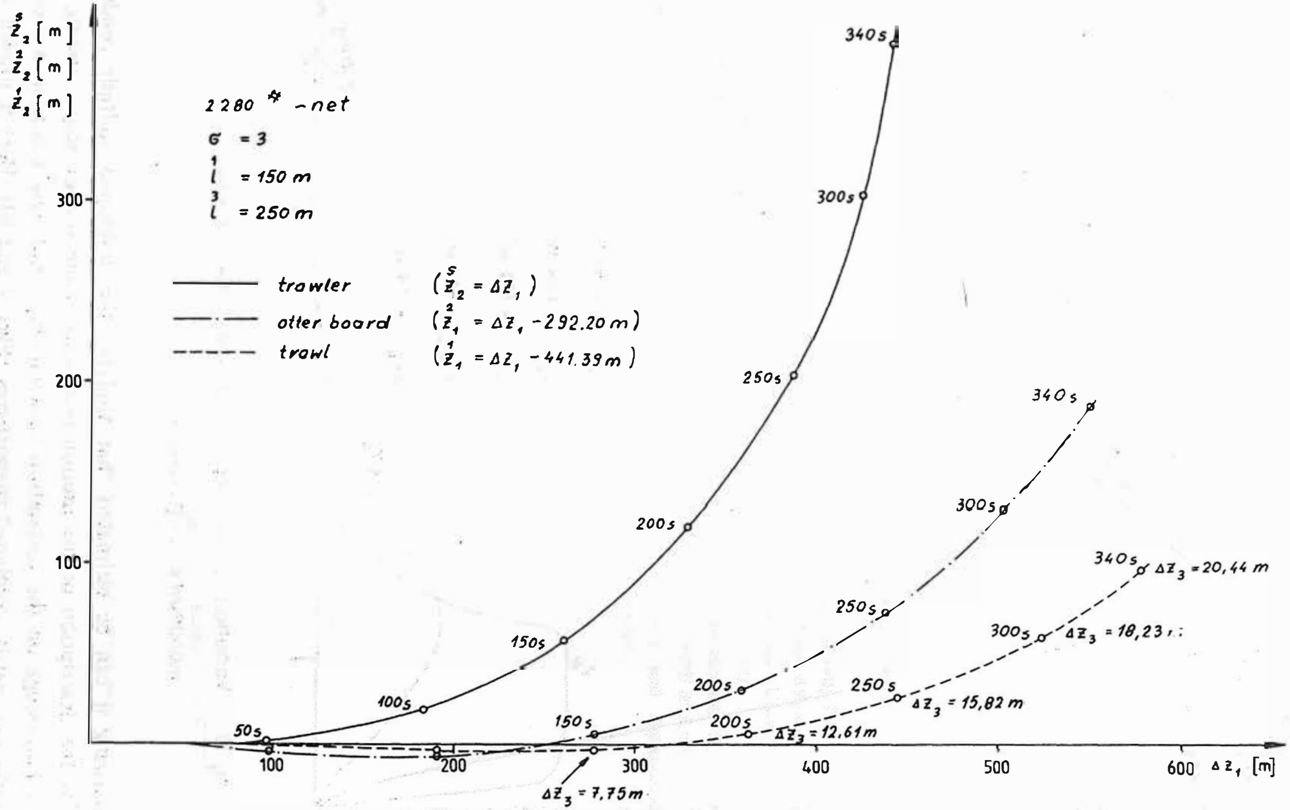


Fig.9 The correlation between ship's otter board's and trawl's motion due to rudder manoeuvre ($\delta_R = 20°$)

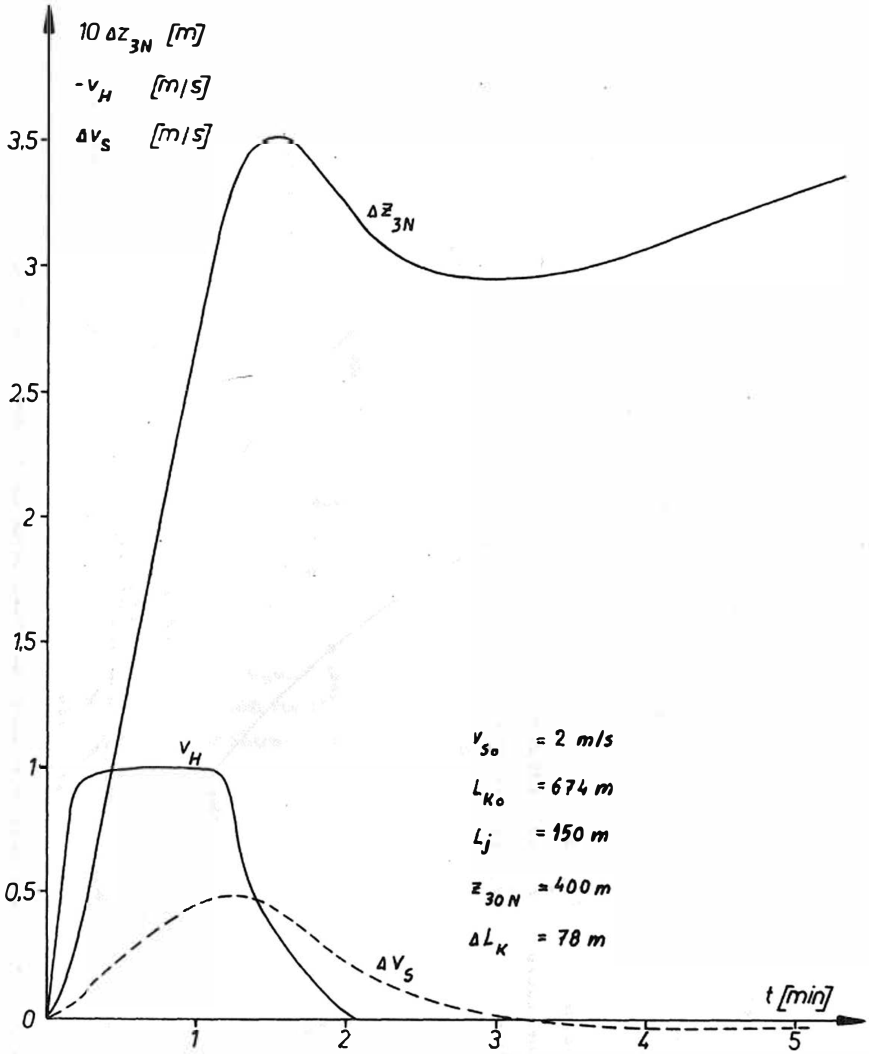


Fig. 10 Variation of net depth and speed due to winch manoeuvre (P/D=const.)

Summarizing it can be estimated that applying the developed multiple pendulum models for the description of the motion behaviour of the system 'ship – fishing gear' important knowledge on the correlation between ship's and trawl's motion is provided due to different, partly combined manoeuvres (Figs. 9 and 10). Here it proved to be advantageous that for sufficiently accurate correspondence with real net paths time – and money – consuming test with full-scale ships and nets may be prevented.

The sufficiently accurate correspondence of the behaviour of net depth determined according to the simplified solution set-up with those determined by means of multiple pendulum models underlines its applicability for the problems of aimed fishing. A calculation method of that kind, which makes according to a given manoeuvre the immediate prediction of the net depth's variation possible as a function of time respect to possible start of manoeuvre, may after corresponding further development be the basis for net's control by means of corresponding manoeuvres of ship or winches while the positions of net and object of fishery are permanently considered.

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LIST OF SYMBOLS

A	reference surface
C	hydrodynamic resistance coefficient
$\vec{F}, F$	vector and absolute value of tensile force of rope
$\overset{s}{F}_1, \overset{s}{F}_2$	longitudinal and transverse force of the ship in X_j – system
$\vec{f}$	tangential vector of rope in Z_i – system
$\vec{G}, G$	vector and value of weight in water
$\overset{s}{I}_3, \overset{s}{I}_{h3}$	mass moment of inertia and hydrodynamic moment of inertia of ship
L	ship's length on water line
$\overset{\nu}{l}, K_K$	length of ν-th towing warp segment or trawl warp for the simple pendulum
$\overset{s}{M}_3$	yawing moment of ship
m	mass
m_{hi}	hydrodynamical mass during motion in the i-th direction
$\overset{\nu}{P}$	mass point
P/D	pitch of variable propeller blade

$\vec{R}$, R	vector and value of hydrodynamic load
S	tow-rope pull of fishing vessel
$\vec{T}$	vector of the force of inertia
t	time
$\vec{v}$, v_i	vector and components of velocity
X_i	axes of ship-fixed coordinate system
X_H	horizontal distance between ship's centre of gravity and topping block
Z_i	axes of space-fixed coordinate system
α	divering angle of towing warp
β	yawing angle.
γ	generalized angle horizontal
δ_R	rudder deflection
δ_{ij}	Kronecker symbol
$\overset{\nu}{\vartheta}$, ϑ	generalized angle vertical or slope angle of towing warp, respectively
ρ	density of water
σ	number of maximum mass points
ψ	course angle of ship

Indices

o	initial value
E	stationary final value
H	heaving speed
N	net and rigging
S	ship
SE	otter board
ν	quantity related to ν-th mass point
Δ	difference between instantaneous quantity and initial value

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WSTĘPNE BADANIA NAD NAPROWADZANIEM WŁOKA PELAGICZNEGO NA ŁAWICE RYB

STRESZCZENIE

Efektywność współczesnego rybołówstwa morskiego można podnieść przez bardziej precyzyjne naprowadzanie narzędzia połowu, np. włoka, na zlokalizowaną ławicę ryb. Jednak przy ręcznym sterowaniu manewrami statku, trafienie włokiem w ruchomą ławicę w wielowymiarowej przestrzeni, daje się zrealizować tylko w nielicznych, prostych przypadkach.

Obecny stan automatyzacji na statkach rybackich, łącznie z rozwojem mikroelektroniki, stwarza techniczne możliwości zautomatyzowania procesu naprowadzania włoka na ławicę, w celu zwiększenia prawdopodobieństwa trafienia.

Zasadniczym ograniczeniem zastosowania tej techniki w praktyce, jest brak prostych algorytmów, opisujących ruch statku i włoka po wykonaniu różnych manewrów.

W artykule omówione są wyniki badań eksperymentalnych, wykonanych na uproszczonym modelu fizycznym statku, z włokiem pelagicznym (rys. 1). Wyniki prac doświadczalnych umożliwiły opracowanie prostego modelu matematycznego do obliczania parametrów ruchu statku i włoka po wykonaniu manewru sterem, śrubą napędową oraz windą trałową z uwzględnieniem wydawania i wybierania włoka. Wyniki prac doświadczalnych i obliczeń przedstawione są na wykresach porównawczych na rys. 5–10. Wyniki obliczeń odwzorowują dostatecznie dokładnie dane doświadczalne.

Michael Meisel, Mathias Paschen, Steffen Wagner

ПРЕДВАРИТЕЛЬНЫЕ ИССЛЕДОВАНИЯ ПРОБЛЕМЫ ПРИЦЕЛЬНОГО РАЗНОГЛУБИННОГО ТРАЛЕНИЯ

Р е з ю м е

Эффективность современного морского рыболовства можно поднять на более высокий уровень путём более точного наведения орудия лова, например, трала, на локализированное скопление рыб.

Однако, при ручном управлении маневрами судна попадание тралов в перемещающийся в многомерном пространстве косяк можно реализовать лишь в несложных случаях и редко.

Современное состояние автоматизации на рыболовных суднах совместно с развитием микроэлектроники создаст технические возможности автоматизирования процесса наведения трала на косяк с целью увеличения вероятности попадания.

Основным ограничением применения этой техники на практике является отсутствие простых алгорит-

мов, описывающих движение системы трал-судно во время маневрирования.

В настоящей статье представлены результаты экспериментальных исследований, которые проводили на упрощённой физической модели судна с разноглубинным тралом (Рис.1). Результаты экспериментальных работ дают возможность разработать простую математическую модель для рассчёта параметров движения системы судно-трал после маневров рулём, винтом и траловой лебёдкой с учётом выборки и выдачи трала. Результаты этих работ, а также рассчётов, представлены на сравнительных графиках на рис. 5-10. Результаты рассчётов с достаточной точностью подтверждают экспериментальные данные.

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