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Fishing technic

CALCULATION OF FISHING GEAR AS DISCRETE MODELS

ZASTOSOWANIE MODELU DYSKRETNEGO W OBLICZENIACH NARZĘDZI RYBACKICH

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The paper deals with a new calculation method of discretizing complicated line system and netting of fishing gear, that makes possible a successive approximation of assesed initial values to the true solution.

INTRODUCTION

As a rule fishing gear includes complicated engineering systems formed by heavy ropes that are subjected to permanent deformation by bending and knotted together. Those ropes are hydrodynamically loaded by the acting inflow and have solid bodies, as e.g. otter trawl boards, towing weights and others, lashed into them. The nets that are applied in this fishing gear may be regarded as special cases of these systems.

The calculation of those engineering facilities seems to cause important difficulties (Stengel a.Fridman, 1977) because of the complicated correlations between shape and acting forces. For the consideration of the single line elements used in the systems by means of models we base on the theory of the flexible twine. It provides the differential equations of the flexible twine

$$\frac{dF_s}{ds} \cdot \frac{dx}{ds} + F_s \frac{d^2x}{ds^2} - r_w = 0$$

$$\frac{dF_s}{ds} \cdot \frac{dy}{ds} + F_s \frac{d^2y}{ds^2} + q = 0 \qquad (1)$$

$$\frac{dF_s}{ds} \cdot \frac{dz}{ds} + F_s \frac{d^2z}{ds^2} + (r_A - q) = 0$$

here:

- F_s — is the tensile force in the twine
- x,y,z — the coordinates of a considered point on the twine
- r_w,q,A — the hydrodynamic loads on sections of twine in the directions x, y, z
- q — the hydrostatic load on sections of the twine
- s — the longitudinal coordinate along the axis of twine

Using empirically determined functions for the shape-depending hydrodynamic loads r_W, r_A and r_q for each closed line segment the shape and the loads of this line segment with known initial load $F_{s,o}$ may be solved by numerical integration as an initial value problem (Stengel a. Fridman 1977).

A connection of various single ropes to a well-defined line system is according to this method possible only by iterative variation of the single initial values, that becomes the more expensive the larger the number of single ropes, because only one special initial value may satisfactory correspond to each point of connection. Therefore solutions have been found for relatively simple connections. as e.g. solutions for the problem of bringing together an echo sounder cable and a trawl towed by trawl warps (Stengel a. Fridman, 1977).

More complicated three-dimensional line systems impose requirements of such a kind to the calculation by means of EDP, that the possibilities of a real solution are lacking soon. In order to calculate areas of nettings a still more complicated system of differential equations may be defined, the solution of which is possible only with important restricting assumptions and preconditions (Pretzsch, 1970; Ivanov, 1971; Leitzke, 1977).

However, real fishing gear is almost without exclusion consisting of several single ropes, heavy single bodies and netting, so with the differential way of consideration in our today's standard of knowledge a useful solution for the complicated whole system fishing gear hardly may be found. At the Wilhelm-Pieck – University of Rostock at the Section of Mathematics and at the Section of Naval Architecture and Marine Technology it has consequently been searched for a possibility of discretizing those systems subjected to permanent deformation by bending and subjected to tension.

The method of finite elements (Hajduk a Osiecki, 1974) that is often applied in structural mechanics is only little productive for the solution of problems in fishing technology, because problems in structural mechanics are mostly basing on fixed boundaries and traction ropes with high initial tension, that are not given for the system trawl warps – otter boards – trawl net.

Another reason for the insufficiency of the Finite-Element-Method with respect to systems subjected to permanent deformation by bending is that it includes nodal equilibriums of forces and moments for the formation of the equations, because it's not possible to transfer moments in the traction system.

For the calculation of complicated line systems at the Wilhelm-Pieck-University of Rostock a method of discretizing has been found, that makes a successive approximation of assessed initial values to the true solution possible (Litzke, 1981; Hackmann, 1982).

MATHEMATICAL-PHYSICAL MODELLING

The considered systems or parts of them with known boundary loads are divided in finite segments, that are regarded as straight rods transferring only tensile forces. The outer loads acting at these single rods are separated in equal parts as point forces. The rod ends are united in knots, in which forces but no moments may be transferred. The knots themselves may be loaded by additional singular nodal forces, as they are typical for towing weights, otter boards, floating means and others. This system may be described by the equilibrium of forces in the knots and by the geometrical shape of the system, which is characterized by the lengths of the single rods and their unknown directions in space.

The way of carrying out the calculation may be demonstrated using a very simple example although no evidences for its admissibility are shown (Leitzke, 1981; Hackmann, 1982).

In fig. 1 a line system is shown between the fixed points A and B, that is divided in 7 elements and where two singular force influences $\vec{F}_1$ and $\vec{F}_2$ are to be noticed, may be mathematically described in the following way.

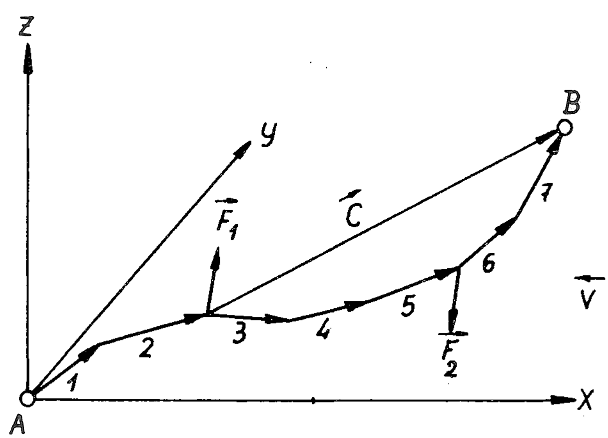

Fig. 1. Simple discrete traction system – line affected by inflow between two fixed coints with additional weights

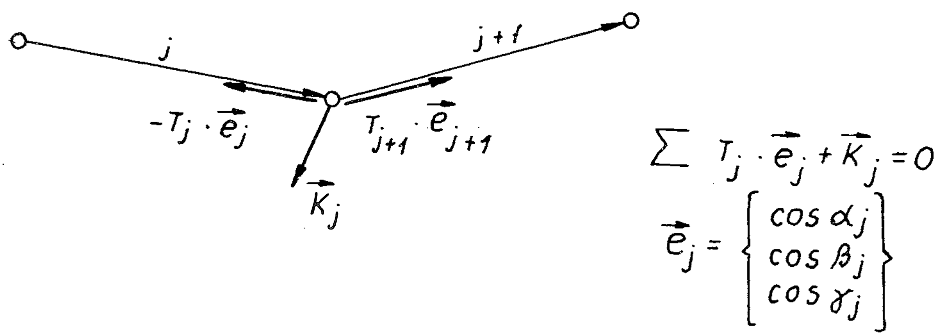

Fig. 2. Equilibrium of forces in the nodes

At first the elements of the line are numbered and their orientation along the line is established in an arbitrary manner. The directions in space are still unknown, i.e. the unit vectors for each element are searched. For tensile forces may be transferred only, those tensile forces are to be determined as being directed away from the node.

From that the equilibriums of forces may be written in the following way:

$$-T_1\vec{e}_1 + T_2\vec{e}_2 = -\frac{1}{2}(\vec{F}_{H,1} + \vec{F}_{H,2} + \vec{q}\,(a_1 + a_2))$$

$$-T_2\vec{e}_2 + T_3\vec{e}_3 = -\frac{1}{2}(\vec{F}_{H,2} + \vec{F}_{H,3} + \vec{q}\,(a_2 + a_3)) - F_1$$

$$-T_3\vec{e}_3 + T_4\vec{e}_4 = -\frac{1}{2}(\vec{F}_{H,3} + \vec{F}_{H,4} + \vec{q}\,(a_3 + a_4))$$

$$-T_4\vec{e}_4 + T_5\vec{e}_5 = -\frac{1}{2}(\vec{F}_{H,4} + \vec{F}_{H,5} + \vec{q}\,(a_4 + a_5))$$

$$-T_5\vec{e}_5 + T_6\vec{e}_6 = -\frac{1}{2}(\vec{F}_{H,5} + \vec{F}_{H,6} + \vec{q}\,(a_5 + a_6)) - F_2$$

$$-T_6\vec{e}_6 + T_7\vec{e}_7 = -\frac{1}{2}(\vec{F}_{H,6} + \vec{F}_{H,7} + \vec{q}\,(a_6 + a_7)) \qquad (2)$$

The only geometrical relation of this special system results from the fact, that the line is spread out between the two fixed points A and B:

$$a_1\vec{e}_1 + a_2\vec{e}_2 + a_3\vec{e}_3 + a_4\vec{e}_4 + a_5\vec{e}_5 + a_6\vec{e}_6 + a_7\vec{e}_7 = \vec{c} \qquad (3)$$

with

T_j – absolute value of tensile force in the element j

$\vec{e}_j$ – unit vector of the element j (Fig. 2)

$\vec{F}_{H,j}$ – hydrodynamic load of the element j

$\vec{q}$ – hydrostatic uniform load of the rope

a_j – length of the element j

$\vec{F}_i$ – singular forces

$\vec{c}$ – length vector between the fixed points A and B

For n elements in the system by splitting equations (2) and (3) up into the components of the three directions in space x,y,z 3.n equations, that are non-linear and do not depend on each other, exist so far for the solution of a set of equations with 4.n unknowns – the components of the unit vectors $\vec{e}_j$ and the tensile forces T_j. The lacking n relations result from the three-dimensional Pythagoras' theorem for the n unit vectors:

$$\sqrt{\cos^2\alpha_j + \cos^2\beta_j + \cos^2\gamma_j} = 1 \tag{4}$$

Non-linear sets of equations, as they follow from the equations (2), (3) and (4), may be solved by means of an approximation method, if corresponding initial values are available for the T_i and $\bar{e}_i$. In the most cases Newton's methods are applied, which are, however, connected with a very high expense of computer technique. The system then requires the solution of sets of equations containing 4.n unknowns.

The hydrodynamic forces depend on shape. They are always calculated a new corresponding to each approximation

$$\vec{F}_{H,j} = \begin{Bmatrix} C_{x,j} \\ C_{y,j} \\ C_{z,j} \end{Bmatrix} \cdot \frac{\rho}{2} v^2 \cdot d_j \cdot a_j \tag{5}$$

where coefficients $c_{x,j}$, $c_{y,j}$, $c_{z,j}$ are empirically gained functions of the angles α_j, β_j, γ_j of the correspondingly obtained approximation.

The method for the solution of this special problem, that has been developed at the Wilhelm-Pieck-University of Rostock, may be considered as an essential simplification as far as computer technique is concerned. The set of equations is solved by means of successive approximation with roughly estimated positive values and a very rough shape for the determination of the hydrodynamic loads given at first.

Then the set of equations formed by the equations (2) and (3) with the estimated T_j and the given lengths a_j is solved as a linear set of equations having three right sides with respect to first approximations for the components of the unit vectors $\cos\alpha_j$, $\cos\beta_j$, $\cos\gamma_j$.

$$\vec{\vec{A}} \cdot \vec{\vec{X}} = \vec{\vec{B}}$$

$$\vec{\vec{X}} = \vec{\vec{A}}^{-1} \cdot \vec{\vec{B}}$$

For the given example according to fig. 1 the matrices read as follows:

$$\vec{\vec{A}} = \begin{pmatrix} -T_1 & T_2 & 0 & 0 & 0 & 0 & 0 \\ 0 & -T_2 & T_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & -T_3 & T_4 & 0 & 0 & 0 \\ 0 & 0 & 0 & -T_4 & T_5 & 0 & 0 \\ 0 & 0 & 0 & 0 & -T_5 & T_6 & 0 \\ 0 & 0 & 0 & 0 & 0 & -T_6 & T_7 \\ a_1 & a_2 & a_3 & a_4 & a_5 & a_6 & a_7 \end{pmatrix} \qquad \vec{\vec{X}} = \begin{pmatrix} \dot{x}_1 & \dot{y}_1 & \dot{z}_1 \\ \dot{x}_2 & \dot{y}_2 & \dot{z}_2 \\ \dot{x}_3 & \dot{y}_3 & \dot{z}_3 \\ \dot{x}_4 & \dot{y}_4 & \dot{z}_4 \\ \dot{x}_5 & \dot{y}_5 & \dot{z}_5 \\ \dot{x}_6 & \dot{y}_6 & \dot{z}_6 \\ \dot{x}_7 & \dot{y}_7 & \dot{z}_7 \end{pmatrix} \tag{6}$$

with $\dot{x}_j, \dot{y}_j, \dot{z}_j$ being approximations for the components of the unit vectors $\vec{e}_j$.

The matrix $\vec{\vec{B}}$ contains just the components in x,y,z – direction of the equations (2) and (3).

In order to correct matrix $\vec{\vec{A}}$ for the following iteration step the equations (4) are applied. For $\dot{x}_j, \dot{y}_j, \dot{z}_j$ being approximate values for the components of the unit vectors $\vec{e}_j$, as a rule the following may be written

$$\sqrt{\dot{x}_j^2 + \dot{y}_j^2 + \dot{z}_j^2} = \chi_j \neq 1 \tag{7}$$

From this the possibility of correcting equation (5) results using the correction of the coefficients of matrix $\vec{\vec{A}}$ and matrix $\vec{\vec{B}}$ according to the k-th approximation:

$$T_j^{(k+1)} = T_1^{(k)} \cdot \chi_j^{(k)} \tag{8}$$

$$\cos \alpha_j^{(k)} = \frac{\dot{x}_j^{(k)}}{\chi_j^{(k)}}, \quad \cos \beta_j^{(k)} = \frac{\dot{y}_j^{(k)}}{\chi_j^{(k)}}; \quad \cos \gamma_j^{(k)} = \frac{\dot{z}_j^{(k)}}{\chi_j^{(k)}} \tag{9}$$

After this the calculation is started again using improved coeficients. As has been shown by extensive test calculations and theoretical investigations, with a rising number of approximations k the correction values χ_j approach the value 1, if there's no full relief of single elements, as it often is the case in nets. Elements with bucking provide $\chi_j < 1$. Proofs for the correctness of this approach are to be found in other papers by Hackmann and by the author.

The iteration may be stopped if the following holds:

$$|\chi_j - 1| < \epsilon$$

where ϵ gives a limit of accuracy.

The advantage of this method lies in the fact that especially the matrix $\vec{\vec{A}}$ is of type (n, n) whereas for full Newton's methods the necessary Jacobi matrix would be of type (4n, 4n). So it is possible to lead very ambitious problems in fishing engineering to their practical solution using large EDP plants whereas at first stationary cases of operation are to be considered only.

APPLICATIONS

Three-dimensional calculation of trawl warps

Trawl warps are characterized by the fact, that their end is not fixed in space depending on the initial force $\vec{F}_0$ (fishing gear).

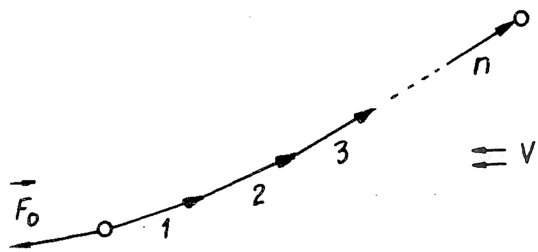

Fig. 3. Modelling of trawl warp

The matrix $\vec{\vec{A}}$ has a very simple configuration:

$$\vec{\vec{A}} = \begin{bmatrix} T_1 & 0 & 0 & 0 \dots & 0 & 0 \\ -T_1 & T_2 & 0 & 0 \dots & 0 & 0 \\ 0 & -T_2 & T_3 & 0 \dots & 0 & 0 \\ 0 & 0 & 0 & 0 \dots & -T_{n-1} & T_n \end{bmatrix} \tag{10}$$

A geometrical equation in the sense of equation (3) does not exist.

The matrix $\vec{\vec{B}}$ contains in its rows 2 to n expressions being analogous to the first line of equation (2).

The first row is

$$\vec{b}_1 = -\frac{1}{2}(\vec{F}_{H,1} + q\,(a_1)) - \vec{F}_o \tag{11}$$

Then the solution again may be obtained using equations (6) and (8) to (9). The form may be found by addition of the vectors $\vec{P}_i = \vec{P}_{i-1} - a_i \cdot \vec{e}_i$ and the tensile forces along the rope by the iterated forces T_j.

System trawl warp – cable – echo sounder cable

Representing the most simple case the problem may be treated as a two-dimensional problem.

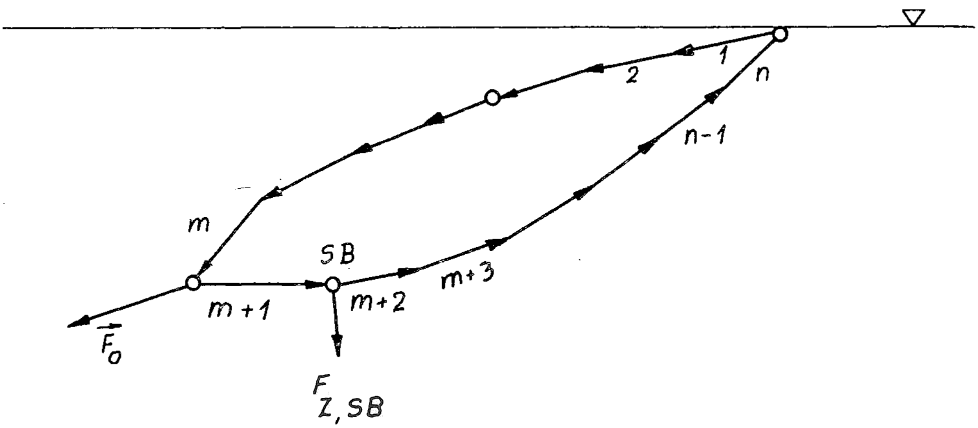

Fig. 4. System trawl warp – cable – echo sounder cable

n–1 equilibriums of forces are obtained, e.g.

$$-T_1\vec{e}_1 + T_2\vec{e}_2 = -\frac{1}{2}(\vec{F}_{H,1} + \vec{F}_{H,2} + q_k(a_1 + a_2))$$

$$-T_m e_m + T_{m+1} \cdot e_{m+1} = -\frac{1}{2}(\vec{F}_{H,m} + \vec{F}_{H,m+1} + q_k \cdot a_m + q_k \cdot a_{m+1}) - \vec{F}_o$$

a.s.o.

It has to be taken into account, that the cables and the trawl warp have different diameters d and different hydrostatic uniform loads, that must be regarded while setting up the matrix $\vec{\vec{B}}$.

The last line of the set of equations results from the fact, that trawl warp and cables must converge at the ship, i.e.

$$\sum_{j=1}^{n} a_j \cdot \vec{e}_j = 0 \tag{13}$$

The calculation is again carried out in the mentioned way. In complicated rope systems closed turns are more often to be found, that have to be modelled analogously to equation (13).

Nets

Nets are no exceptional case as far as the calculation method is concerned. They just show some special characteristics owing to their structure.

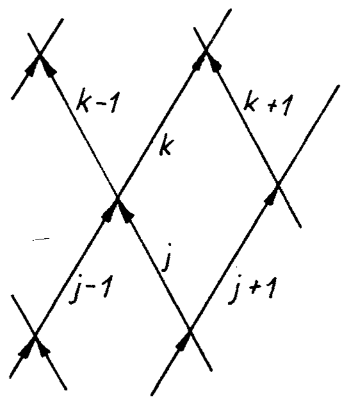

Fig. 5. Section of the net

In the interior of the netting area the following equilibriums of forces are existing

$$-T_{j-1}\cdot\vec{e}_{j-1} - T_j\cdot\vec{e}_j + T_{k-1}\cdot\vec{e}_{k-1} + T_k\cdot\vec{e}_k = -\frac{1}{2}\sum_{j-1,k-1,k}\vec{F}_H \tag{14}$$

and the condition of closed meshes

$$a_j\cdot\vec{e}_j + a_k\cdot\vec{e}_k - a_{k+1}\cdot\vec{e}_{k+1} - a_{j+1}\cdot\vec{e}_{j+1} = 0 \tag{15}$$

The edge of those nets may be limited in the model by side ropes, net tips or other rope elements that have to be treated analogously or by a section of the system, where the sectional forces are to be placed in the sectional node. In other publications (Leitzke, 1981; Leitzke a. Niedzwiedz, 1982; Leitzke, 1983) the approach is described more in detail.

The solution of those problems in the first applications has lead to very interesting results on net structures that allow the conclusion, that in future a large number of correlations having been only experimentally determined so far can be investigated more in detail.

An example of a calculated net shape by Niedzwiedz has the objection to show the meaning and usefulness of the new method. A front part of a cable net with hexagonal meshes (Type 6PJ 119–110, fig. 6) loaded by initial forces $\vec{F}_i$ is influenced by current forces, weight and buoyancy forces. Introduced so-called auxiliary elements that must be normal to the x-z-cross-sectional plane in the case of solution (9), it is possible to reduce the type of the system matrix to the half and to consider only the starboard side of the front part of the cable net.

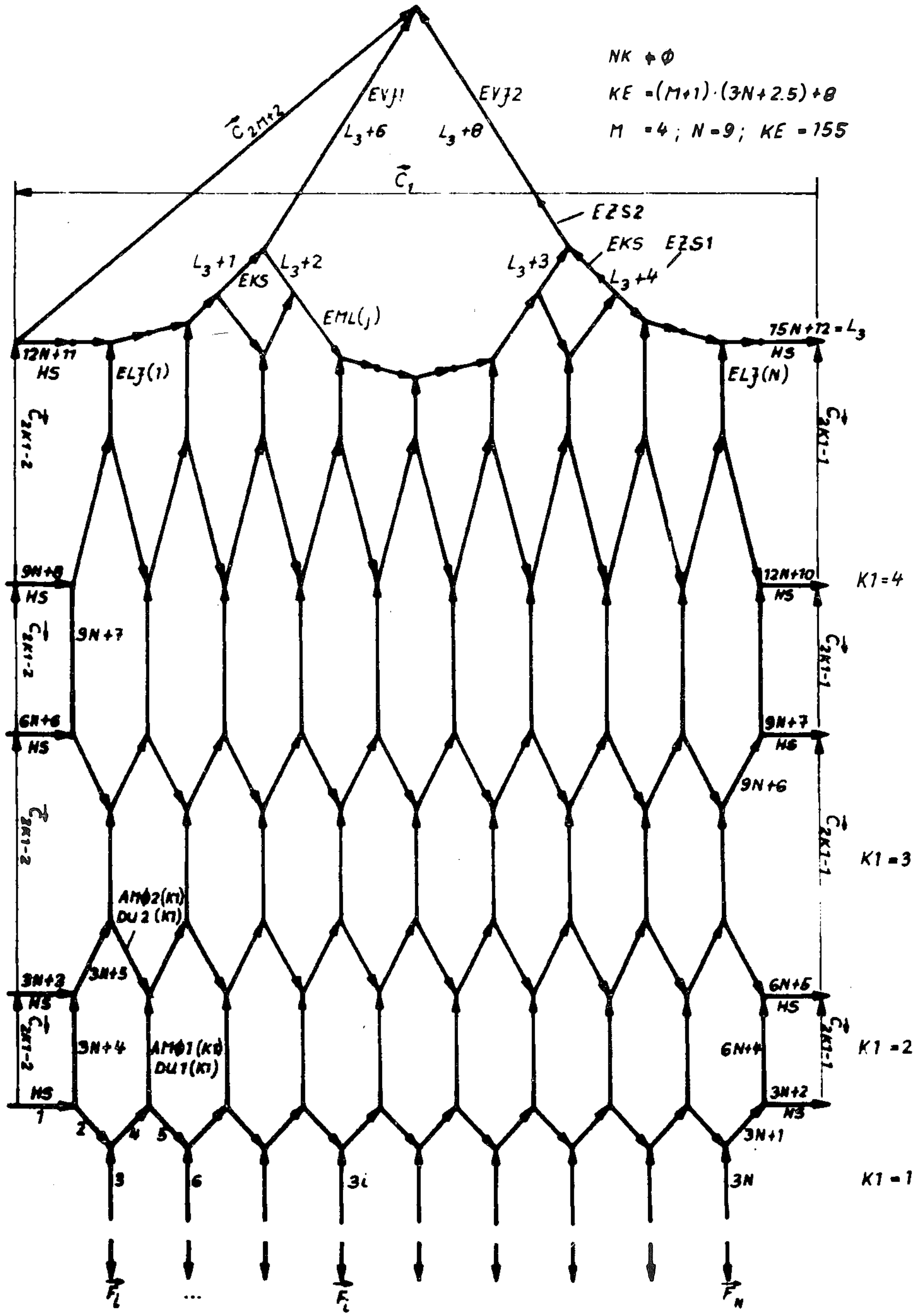

Fig. 6. Front part of cable trawl with hexagonal meshes

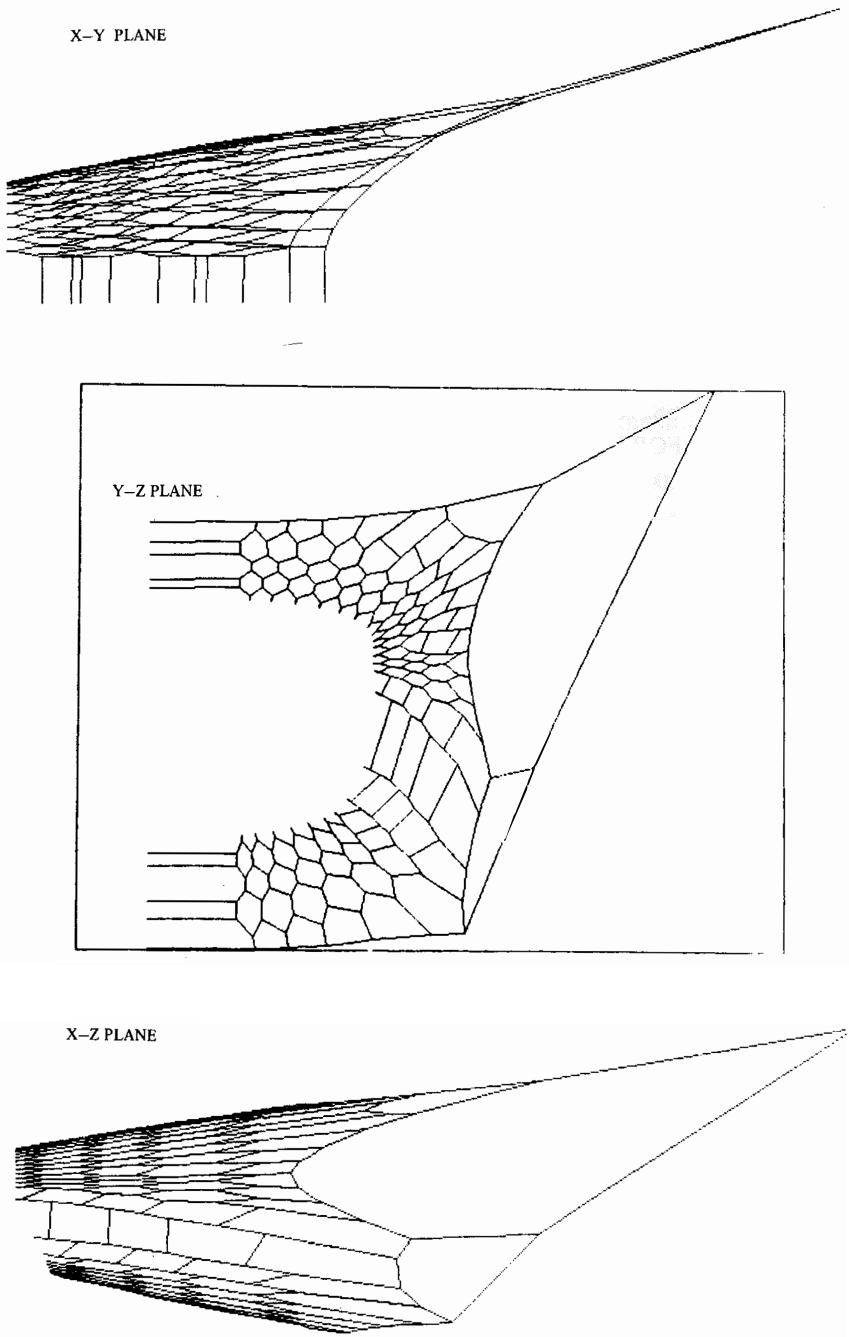

Fig. 7. Hanging shape of the front part of cable trawl, calculated by computer in 76 iteration steps.

The result shown in fig. 7 is the hanging shape of the front part of the net with flow around it. The applied calculation program JAVONE, written in ESER-FORTRAN (calculator type ESER 1035), can be applied as an extension to the given problem for manifold purpose, so for
- determination of the towing weight according to a given barrage height
- determination of different additional lengths according to given form parameters
- calculation of the otter board position in water
- calculation of necessary wing floaters for surface fishery.

Explanations for the calculation program JAVONE

EDP machinery:	ESER 1035 ifH Rostock-Marienehe
Language:	FORTRAN
Store demand:	200000 Byte
Computing time:	ϕ 40–50 min CPU (pure) computing time up to the solution
Capacities:	Half of the front part of the cable net is calculated, being located in the 1st and 4th quadrants (y–z plane); its cables are loaded by internal forces, that are caused by the trawl pocket.

Here the following variants are possible:

1) Constructions:
   a) Calculation of a net with long cables with/without legs
   b) Calculation of a net's front part with hexagonal meshes with long cables with/without legs
   c) Calculation of the presented front parts of nets including starboard otter board and trawl warp
   d) Calculation of front part of cable nets, that are towed near the water surface, so that additional lifting forces are to be noticed at the wing tip of trawl

2) Aim of calculation:
   a) Calculation of the cable net's front part (1c)
   b) Iterative rating of the towing weight according to a given vertical trawl opening
   (and) c) Iterative rating of otter board spread according to a given width at the transition trawl pocket/front part of cable net
   (and) d) Iterative rating of additional lengths in the lower leg and in the lower door leg according to a given x-distance of the bosom centres
   e) In connection with 1d iterative rating of additional wing floaters for surface fishery

- In order to follow the supposed symmetry, independent wires HS have been introduced, that must in the case of symmetry be located vertically to the x-z sectional plane (cf. HP pictures x-y plane + y–z plane 38^{th}+76^{th} iteration step).
- The matrix $\vec{\vec{A}}$ of the cable net's front part without trawl warp is of type (KE, KE).

KE = (M+1)*(3*N+2.5)+8

M = number of series of three-strand knots
N=NO+NS NO – cable in upper wing
NS – cable in side panel

(e.g. for EMMY KE = 365)

(≚ 6PJ 119/110 for supertrawler)

- assential piece for solving matrix $\vec{\vec{A}}$ is a block of programmes for the calculation of large and sparsely occupied matrices.

  (NNE $\leqslant 0{,}03 \cdot KE^2$) MNE = non-zero elements according to the factorization of $\vec{\vec{A}}$

- Results:
  - direction cosines of all KE elements
  - tensile forces of twine of all KE elements
  - hydrodynamic loads of all KE elements
  - extended element lengths
  - punched tape of the graphical presentation of the results, this punched tape should be usable after conversion in calculators of the type KRS 4200 and also for the HP calculator

List of symbols

$\vec{\vec{A}}, \vec{\vec{B}}, \vec{\vec{X}}$,	system matrices	
$\vec{F}_i$	forces	N
T_i	tensile forces	N
a_i	element lengths	m
$\vec{c}$	distance vectors	m
d_i	diameter of element	m
$\vec{e}_i$	unit vectors	–
q	hydrostatic load	NM^{-1}
r_i	hydrodynamic load	NM^{-1}
s	longitudinal coordinate	m
v	velocity	ms^{-1}
x,y,z	coordinates	m
x_j, y_j, z_j	direction components	–
χ_j	corrective factor	–
ρ	density	kgm^{-3}

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ZASTOSOWANIE MODELU DYSKRETNEGO W OBLICZENIACH NARZĘDZI RYBACKICH

STRESZCZENIE

Rybackie narzędzia połowu zbudowane są z reguły ze złożonego układu wiotkich, ciężkich cięgien, zaopatrzonych dodatkowo w elementy uzbrojenia o stałym kształcie (ciężarki, pływaki, rozpornice). Tkanina sieciowa stanowi szczególny przypadek układu wiotkich cięgien. Podczas pracy narzędzia na jego części działają siły hydrostatyczne i hydrodynamiczne.

Obliczenia inżynierskie tego rodzaju konstrukcji, zmieniające kształt pod wpływem sił zewnętrznych, są zagadnieniem złożonym i dotychczas nierozwiązanym. Nowa metoda obliczeń inżynierskich, zaproponowana przez autorów artykułu, polega na podzieleniu (dyskretyzacji) układu na skończone odcinki (pręty), łączące się w węzłach (rys. 2). Cięgna przenoszą jedynie siły rozciągające. Nie są natomiast przenoszone w węzłach momenty sił.

Konstrukcję taką opisać można za pomocą układów równań nieliniowych, uwzględniających warunki równowagi sił w węzłach oraz długość i położenie w przestrzeni poszczególnych prętów. Układy równań dają się rozwiązać za pomocą rachunku macierzowego metodą iteracji przy użyciu elektronicznej maszyny cyfrowej.

W pracy podane są przykłady zastosowania nowej metody do obliczeń elementów narzędzi rybackich (lina, tkanina sieciowa, przód włoka z uzbrojeniem).

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ПРИМЕНЕНИЕ МЕТОДА ДИСКРЕДИТАЦИИ В РАСЧЁТАХ ОРУДИЙ ЛОВА

Р е з ю м е

Орудия лова конструируются, как правило, из системы гибких тяжёлых нитей. Орудия эти вооружаются элементами с постоянной формой (грузами, поплавками, распорными досками). Сетное полотно является особенным случаем сочетания гибких нитей. Во время промысла на части орудия лова действуют гидродинамические и гидростатические силы.

Инженерные рассчёты этого рода конструкции, изменяющих свою форму под влиянием наружных сил являются сложной и пока неразрешенной проблемой. Новый метод инженерных расчётов, предлагаемый авторами, заключается в разделении (дискредитации) системы на конечные отрезки (стержни), соединяющиеся в узлах (Рис.2).

Гибкие нити переносят только растягивающие силы, моменты сил ими не переносятся.

Такую конструкцию можно описывать при помощи системы нелинейных уравнений, учитывающих условия равновесия сил в узлах, а также длину и размещение в пространстве отдельных стержней. Системы уравнений разрешаются при помощи матричного расчёта методом итерации с применением электронно-вычислительной машины.

сетного полотна, передней части трала с вооружением).

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