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Some Considerations to the Non-Uniform Motion of Trawl Systems

by

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1. Introduction

By the order of industrial branches deep-sea fishery and naval architecture and in the frame of direct scientificall-technical co-operation with the Sovjet Union (Technical University of Fishing Industry and Economy, Chair "Fishing Technique" in Kaliningrad; Headmaster of the Chair Prof.Dr.sc.techn. A.L. Fridman) the Special Field of Fishing Technique of the Wilhelm-Pieck-University of Rostock has dealed among others with the elaboration of mechanical-mathematical models of pelagic trawl systems in the recent years.

In the present contribution it shall be informed about the works performed.

2. The Directed Fishery from the View Point of Mechanics

An important way for increasing the effectivity of pelagic trawling is the realization of the directed fishery, i.e. the controlled motion of the trawl towed towards the moving shoal. Several authors (s. [1]; [2]; [3], [4] a.o.) have referred to the benefit to be achieved by that. The directed motion of the pelagic trawl towards the moving shoal implies:

- sufficient information on the catching object;
- mathematical description of catching system's motion;
- methods of the approach to the shoal.

To the informations on the catching object first of all belong the information on the coordinates of the shoal centre in dependence on time. The information on measurements of shoal, the biological characteristics of fishes, the behaviour in the fishing zone a.s.m. belong to that as well.

To the mathematical description of motion of the catching system it belongs:

- the technical description of the catching system and its analysis;
- the argument of the degree of accuracy and detail of description of the systems investigated;
- determination of physical laws being followed by the subdomains of the system investigated;
- elaboration of mechanical-mathematical models and elaboration of a mechanical schema, choice and classification of the characteristic parameters and determination of the general laws being followed by both the system in its entirety and its individual elements.

On the choice of parameters of the system it is appropriate to divide them into three groups [5] :

1. Variable characteristic parameters describing directly and completely the kinematics of the system at an arbitrary moment of towing. The generalized coordinates as well as the velocities are belonging to this.
2. Steering parameters, that means quantities, which may be changed during towing process and with which in the consequence we are able to change the motion's character. To these parameters it belongs the speed of ship, the length of the lowered trawl line, course angle, several active steering forces, which may be fixed to sheering body or trawl a.o.m..
3. Project parameters. That are such parameters remaining constantly during the towing process as different masses, invariable geometrical characteristics a.o.m..

The whole of all variable states conditioned as function of time may be conditioned as components of a certain vector as well as denoted as state vector of the system during one catching cycle [5]

The whole of all steering parameters may be in analogy to it also conditioned as a certain vector as well as denoted as a steering vector [5] .

Under Method of approach of the trawl to the shoal it is understand the information of the one or other differential or fin...

relations between the kinematic parameters of the motion of catching system and of the shoal characterizing the comparative motion during approaching process.

Choosing a certain method of approach the catching system is forced by variation of the steering vector to make a motion depending on the motion of shoal centre leading in final result to the catch of shoal through the opening of trawl. The methods of approach may be obviously different and are mainly depending on the possibilities of variation of the state vector of the system by the aid of the steering vector.

In the present fishing practice the state vector is influenced by the variation of ship's speed, course angle and lengths of trawl line. But in this case the variation of these parameters takes place separated from another or at the same time.

From the representations it follows that the motion of pelagic trawls is giving some problems.

Subsequently representations to methodical proceed and elaborated models shall be made.

3. To the Methodical Proceed

The real fishing tools represent a very complicated system consisting of a number of different rigid and flexible bodies such as trawl lines, steel hawsers in the fore net and trawl (see fig.1). The setting up of an equation of motion for every element of the fishing tools gives the equation necessary for determination of the unknown quantities of motion and the connecting forces. Because of the high expense and absence of decisive share as description of the connection between shape and forces acting on the trawl at non-uniform motion a.o.m. as well as under taking into account of the economic possibilities and the possibilities of the available computer technique it must be referred to simplificated models. These models have to reflect the essential geometrical quantities and forces.

In this case there are two ways:

1. All subsystems are fitted with the same depth with regard to the adaptation on the reality of the total system.

2. Individual subsystems are approximated to the reality as well as possible, while other subsystems are given less exactly.

The first way is theoretically possible; however, coming to a practical statement an enormous time expense is necessary. The second way used by the special field of fishing technique has the advantage that relative short-term statements about the behaviour and influence of individual subsystems on the total system are possible. Such statements, however, are urgently necessary for the directed shoal approach and for the interpretation of systems for them as well as the design of trawl systems in general. Additionally they are giving information about possible and permissible simplifications.

4. MathematicalModels of the Pelagic Trawl System

A single pendulum is to be considered as most simple model of a pelagic one-ship trawl system. The usual case is the spatial single pendulum [6] as well (see fig.2). The masses, weights and drag of trawl and shearing body are combined in the point like masses of pendulum.

The trawl lines are considered as ideal flexible, mass free, infinite thin, inextensible filaments with constant length. The motion of ship is controlled on semicircular paths or after straight-lined changing of courses by initial speed and boundable phase of acceleration.

There is an applicable program for the electronic data processing R 300 (PRØGRAM R 5) for this model. This model includes the two special cases of vertical single pendulum [7] and horizontal single pendulum ([8] , [9] , [10]).

The special case of vertical single pendulum is present, if the ship is towing without changing of course. If setting the weight forces equal zero we get the special case of horizontal single pendulum.

The forces acting on the lines (trawl lines, steel hawsers) can be taken into account in the first approximation by rod pendulum models. The scheme of an even double-rod pendulum model of pelagic one-ship trawl systems [11] , treated in the special field of fishing technique is represented in fig.3. At this model the trawl line and the steel hawser are modelling as rigid rods and loaded with forces of inertia and weight and hydrodynamic forces, the latter having points of application, the position of which is determined by the coefficients k and k_1. An operation of the winch (haul in and lowering of the trawl line) is taken into account. Trawl and shearing body are point like. Weight and drag are acting on shearing body, weight is acting on the trawl, drags and components of a constant tensile force in the echo probe cable in the mounting point are acting on the trawl (T_o, T_m). The ship's motion is controlled by the initial speed and phase of acceleration. There is an applicable program for the electronic computer R 300 (PRØGRAM PEND). The double-rod pendulum model includes two special cases.

Setting the forces acting on the steel hawser and the length of the steel hawser equal zero, we obtain a single-rod pendulum [12]. Setting the forces acting on the trawl lines and on the steel hawser in the fore trawl equal zero, the double-rod pendulum is reduced to a single double-pendulum [13] (PRØGRAM DØPEND).

The mathematical-physical description of the behavbur of motion of the pendulum model presented here leads to general differential equations of the 2nd order and systems of coupled differential equations of the 2nd order respectively. Their solution is of no problematic nature with the aid of numerical methods by means of the electronic data processing, proceeding from that due to the small accelerations occuring in the fishing practice some forces of inertia may be neglected. Besides these simple models, complicated models of pelagic one-ship trawls - here being denoted as system models - have been elaborated. Such models are denoted as system models at which for the single subsystems of the total system pelagic one-ship trawl (ship, trawl line winches, shearing body, trawl) from which a subsystem or several subsystems are approximated to the reality as far as possible, equations are being formulated which are connected with another on the section points. System models represent a qualitatively higher reflection of the reality.

In fig.4 a ship model is represented under special regard of the motion of shearing body [14]. The special feature of this model is that the motion of the shearing bodies has 6 degrees of freedom. The shearing body and forces acting on him are corresponding to the reality. Trawl line and steel hawser are considered to be ideal flexible, unfinite thin, mass less, inextensible filaments. The trawl is point like and is loaded by mass, weight and hydrodynamic forces.

The ship's motion is straight-lined and uniformly accelerated within an acceleration phase.

For this system model there is an applicable computer program for the large computer BESM6 (PROGRAM BCL). In fig.3 a system model with special regard to the trawl line [15] is represented. At this model the trawl line is considered to be an ideal flexible, inextensive, heavy filament. Forces of inertia, weight and tensile as well as hydrodynamic forces are acting on the trawl line, corresponding to reality. The length of the trawl line may be changed by operation of the winch. The steel hawsers are considered to be infinite thin, inextensible, ideal flexible, mass less filaments. Shearing body and trawl are point like and are admitted with weight, mass and hydrodynamic forces. The motion of the ship's point after straight or semicircular changes of course is uniform or during a phase of acceleration uniformly accelerated.

For this model there are applicable computer programs for the large computer CDC 3300 and BESM6 (PROGRAM BCLFF). With this program the method known from literature [20], differing by another methodical proceeding from the ones presented here and to be considered as an approximation method restricted on small course angles, is further developed. Furthermore this program includes the special case of vertical filament pendulum [21]. A speciality of this model resulting from the real representation of the trawl lines is the occurance of partial differential equations for this subsystem. In a thesis [16] recently presented two further system models of pelagic one-ship trawl systems are represented. This thesis has been elaborated in co-operation between the Technical High School of Navigation Warnemuende/Wustrow, the Nationally Owned FirmlPeople's YardlStralsund and the Special Field of Fishing Technique of the Wilhelm-Pieck-University of Rostock. Both models are going to consider the motion of the trawl system in the vertical plane, i.e. they cover the straight-lined ship's motion, only. All subsystems are considered on both models: the trawl, shearing bodies, trawl lines, thrust equipment of ship and trawl line winch. In the one model the trawl and steel hawsers are reduced to a point mass system. By this the four real steel hawsers will be replaced by a spare steel hawser, which is considered as connecting line to the shearing body reduced to a point mass, too. Both trawl lines will be combined to a heavy inextensible spare trawl line loaded by hydrodynamical forces, the trawl line being existing on an eligible number of straight-lined line elements. As possibilities for the influence of the path of motion of the trawl a variation of the propeller pitch (controllable pitch propeller) is provided.

The measures mentioned may be started separately or simultaneously.

The other model deviates from this in the following respects:

- the trawl and shearing body are combined to a point mass, i.e. a spare steel hawser is absent;
- the number of the straight-line line elements of the spare trawl line is limited on three ones;
- beside the haul in the lowering of the trawl line is also regarded as possibility for influencing the trawl line;
- in the first approximation the influence of sea way is seized.

For both models there are applicable programs for the large computer BESM6 (PROGRAM VSCHWA and PROGRAM NEVEST).

From the representations it can be seen that in the course of recent years by intensive research a series of computer procedures graded in the representation of reality, have been made available and meeting the present demands of the practice of research and development.

These models allow especially a calculation of path variants for the motion of pelagic trawls as well as a calculation of the ship and wind load to be expected in the shoal approach.

These models, however, include the possibility of static calculation of design for fishing systems, too.

5. Further Development of the System Models

First of all the further development of system models has to be orientated to seize the influence of the rudder-angle on the ship's motion with the trawl. A first step would be the coupling of the equations of motion of the vessel, including the rudder-angle with the system model according to fig.5, on which the path kinematics of the vessel is assumed to be known. The realization of this problem requires a narrow co-operation between the special fields of fishing technique and fluid dynamics.

A further step is the better adaptation of the trawl sack on the reality. On all models the trawl sack is reduced to a point mass admitted with forces of gravity, forces of inertia and hydrodynamic forces as well. To the better adaptation of the trawl sack on the reality a method for calculation of the trawl shape and trawl resistance at given mesh size, diameter of filament and given trawl style is necessary. There is shown a way with the methods for calculation of the trawl shape and resistance with given style for rotational trawl covers at v = const. [14], [17].

First of all these methods must be extended in such a way that the calculation of trawl shape and trawl resistance of real trawls strongly deviating from the rotational trawl covers becomes possible, too. The calculation of the non-uniform motion of trawl structures represents an entire new territory. Since the forces of inertia occuring with the motion of the trawl are very small and under circumstances may be neglected, it seems to be possible to think of the non-uniform motion of the trawl as sum of motions at v = const.

At the elaboration of such a method for determination of the shape and resistance at given style we have to note, that it is here not a question of a simple reversal of the present [18] and design method [19] being under elaboration respectively, with which the trawl shape, mesh size and strengths of filament are given and the mesh numbers necessary for the formation of this trawl shapes (and with that style and setting distribution) as well as the tensile forces and the drag are determined.

A further application of the models developed for the purposes of the pelagic one-ship trawl fishing presents itself on the calculation of the path of motion and loading of towed instrument carriers for the ocean research.

An intermediate application of the present models, however, is possible in limits, only. The cause of this is the particularity of the application of towed instrument carriers - very long and thin tow-ropes (operation depth till 6000 m), small forces transmitted from the tow-body on the tow-rope, active controllability of the tow-body in a narrow region.

These particularities are making necessery this modification of the present programs. By that the modification particularly consist therein to keep the tow-body actively controlled and coupled with the tow-rod in a given position.

The small initial forces and large strengths of line make furthermore a possibly exact calculation of the tow-rod necessary, first of all in the neighbourhood of the tow-body.

Summary

In the present paper the directed fishery is characterized from th view point of mechanics. Furthermore explanations to the methodica proceeding on solving of problems regarding the non-uniform motion of trawling systems are made. It is shown that it will be more advantageous to create models on which one is approaching some subsystems to the reality as well as possible and other subsystems interpreting less exactly.

The models of pelagic one-ship trawling systems are represented worked out on the special field of fishing technique at the Wilhelm-Pieck-University of Rostock in the recent years. At this the models are also dealed with known from the literature.

In conclusion considerations to further improvement of the present models of pelagic one-ship trawling systems are made.

Applied Symbols

o, n, m	–	stationary axial systems
T	–	tensile force
G	–	weight
W	–	drag
A, F_a	–	hydrodynamic drive
Q	–	weight in water
q	–	weight per metre of the trawl in water
F_h	–	hydrodynamic moment of inertia
M_I, M_{II}, M_{III}	–	moments
M, M^*	–	mass and mass plus added mass respectively
M_h	–	added mass
q_o	–	mass per metre of the trawl
a	–	acceleration
$\ddot{o}$	–	component of acceleration in o-direction
$\ddot{n}$	–	component of acceleration in n-direction
$\ddot{m}$	–	component of acceleration in m-direction
v	–	velocity
$\dot{n}$	–	component of velocity in n-direction
$\dot{m}$	–	component of velocity in m-direction
v_o	–	initial velocity
t	–	time
L	–	length
B	–	distance
k, k_1	–	coefficients
$\psi, \varphi, \varkappa$	–	angle
S_1, S_2, S_3, S_4	–	points of application of hydrodynamic forces and moments of inertia, respectively

List of Figures

<u>Indices</u>

S - ship

SB - shearing body

N - trawl

J - steel hawser in the fore trawl

[illegible] - trawl line

B_a - acceleration - start

B_e - acceleration - end

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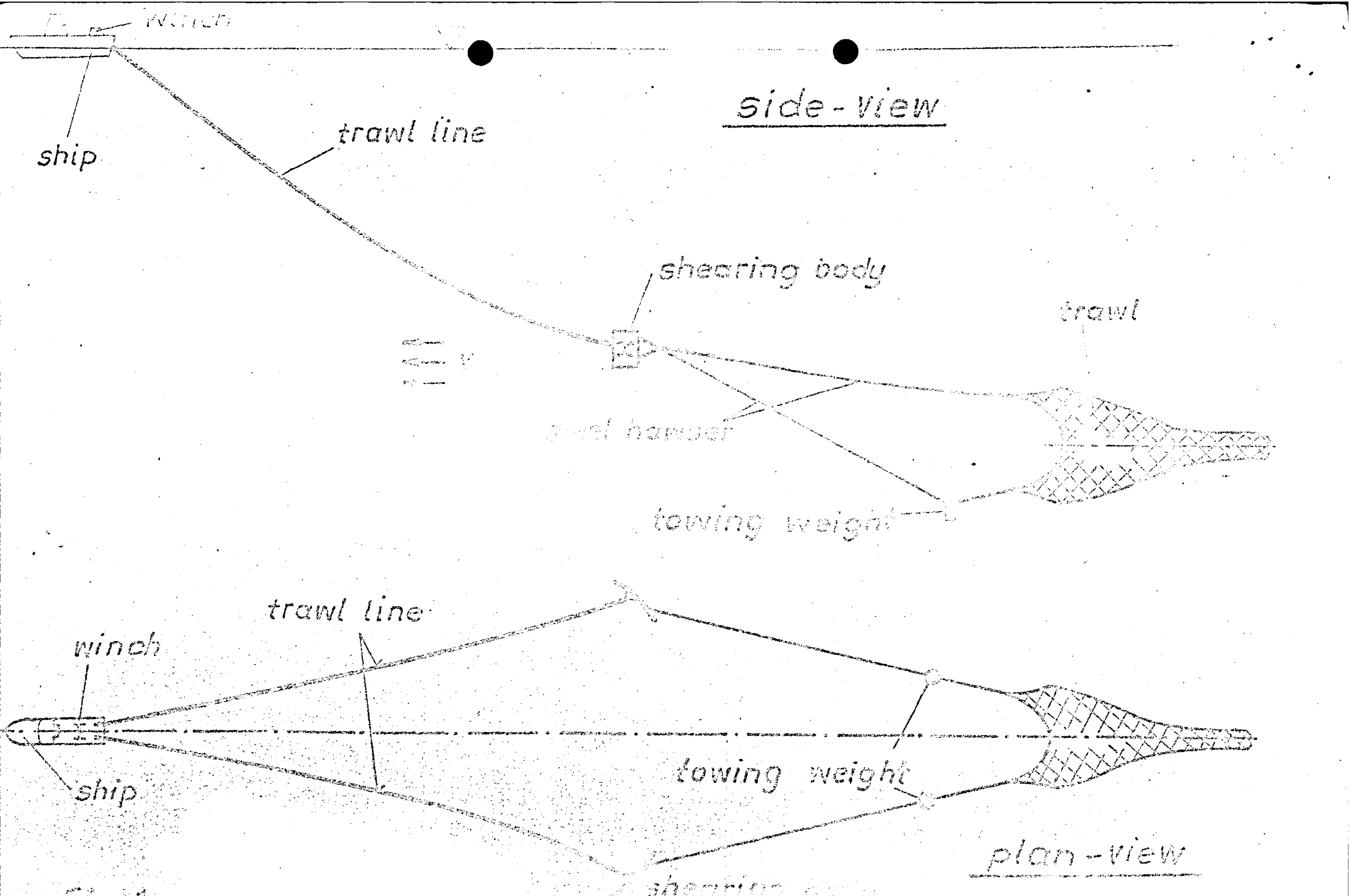
Résumé

Dans le présent article, la pêche systématique est caractérisée du point de vue de la mécanique. On fait en outre un exposé du procédé méthodique dans la solution de problémes concernant le mouvement non uniforme de systémes de chalut. Il est démontré qu'il est plus favorable de créer des modéles ou quelques systémes partiels sout approches le plus possible de la réalité et/ou d'atures systémes partiels sout reproduits moins exactement.

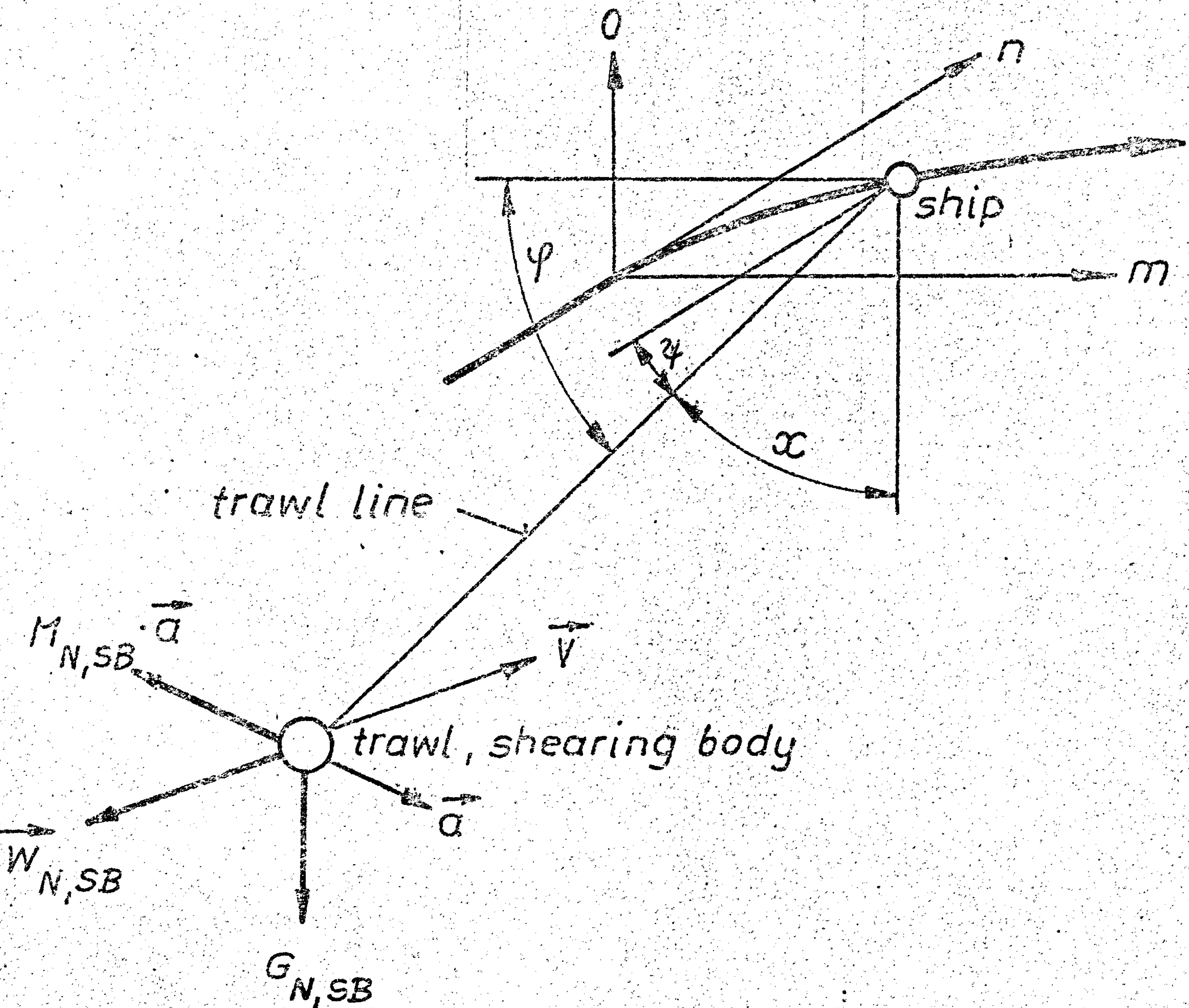
L'article présente les modéles des sysémes de chalut pélagique á un bateau mis au point ces dernières années au département scientifique Technique de pêche de l'Université "Wilhelm Pieck" et s'occupe également, des modéle sconnus par le littérature.

En conclusion des considérations sont faites sur l'amélioration ultérieure des modéles présentés de systémes de chalut pélagique á un bateau.



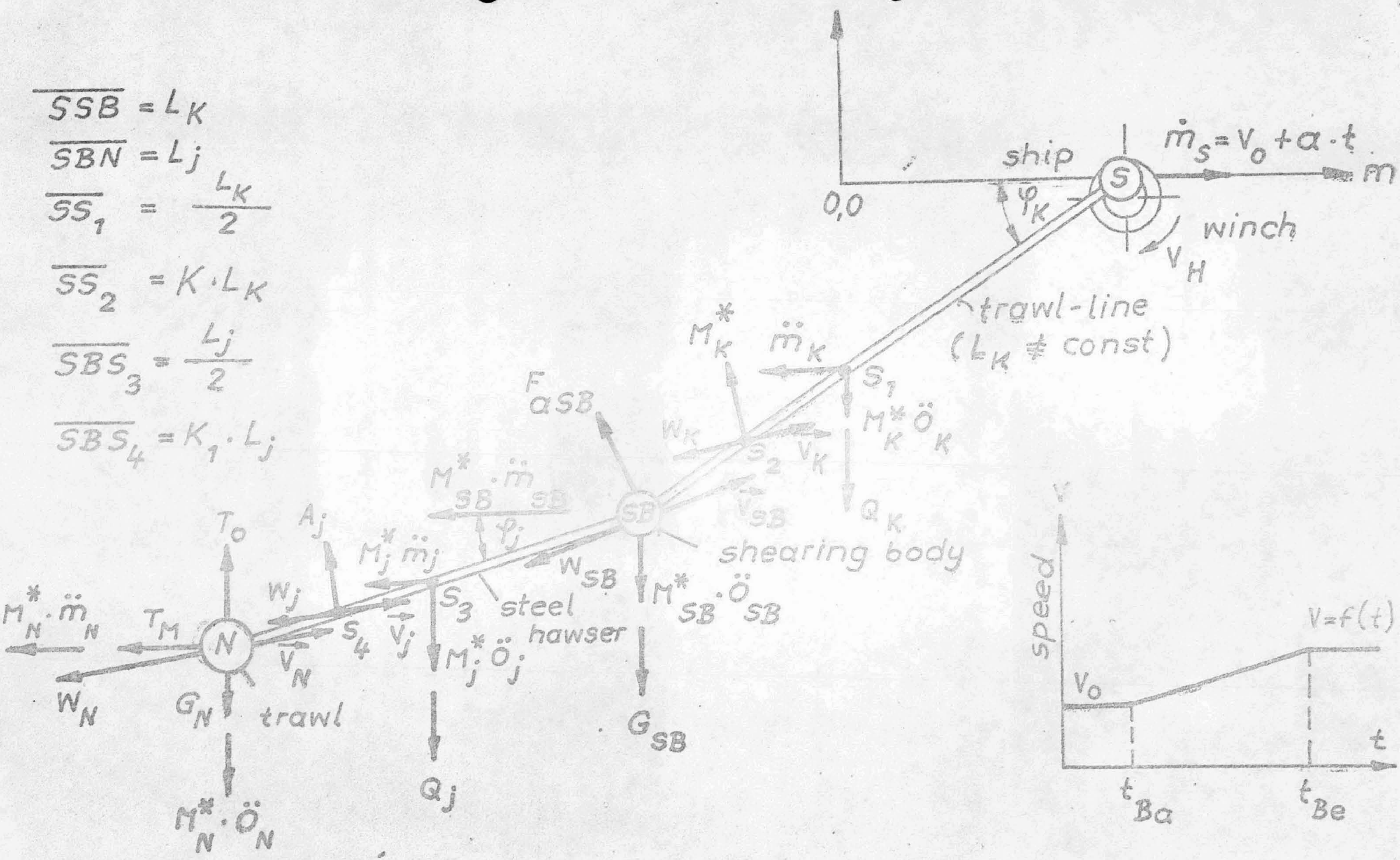
side-view
ship
trawl line
shearing body
trawl
v
towing weight
trawl line
winch
ship
towing weight
plan-view

Fig. 1



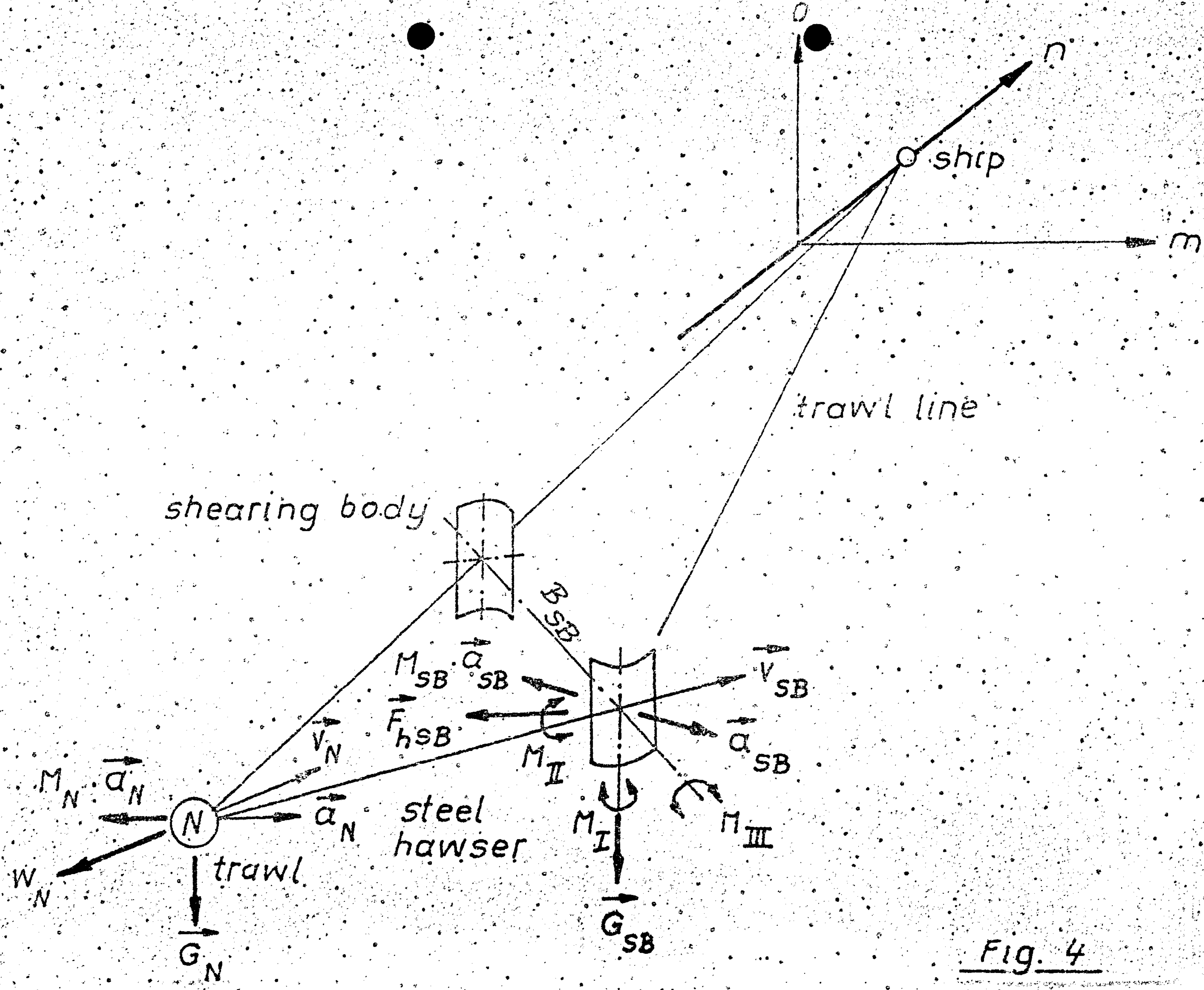
0
n
ship
m
φ
ψ
x
trawl line
$M_{N,SB} \cdot \vec{a}$
$\vec{V}$
trawl, shearing body
$\vec{a}$
$\vec{W}_{N,SB}$
$G_{N,SB}$

Fig. 2



SSB = LK
SBN = Lj
SS1 = LK/2
SS2 = K·LK
SBS3 = Lj/2
SBS4 = K1·Lj
ship
0,0
m
winch
trawl-line
(LK ≠ const)
shearing body
steel
hawser
trawl
speed
V=f(t)
t
tBa
tBe

Fig. 3



o
n
ship
m
trawl line
shearing body
B_{SB}
$M_{SB} \cdot \vec{a}_{SB}$
$\vec{v}_{SB}$
$\vec{F}_{hSB}$
$\vec{v}_N$
M_{II}
$\vec{a}_{SB}$
$M_N \cdot \vec{a}_N$
N
$\vec{a}_N$
steel hawser
M_I
M_{III}
W_N
trawl
$\vec{G}_{SB}$
$\vec{G}_N$

Fig. 4

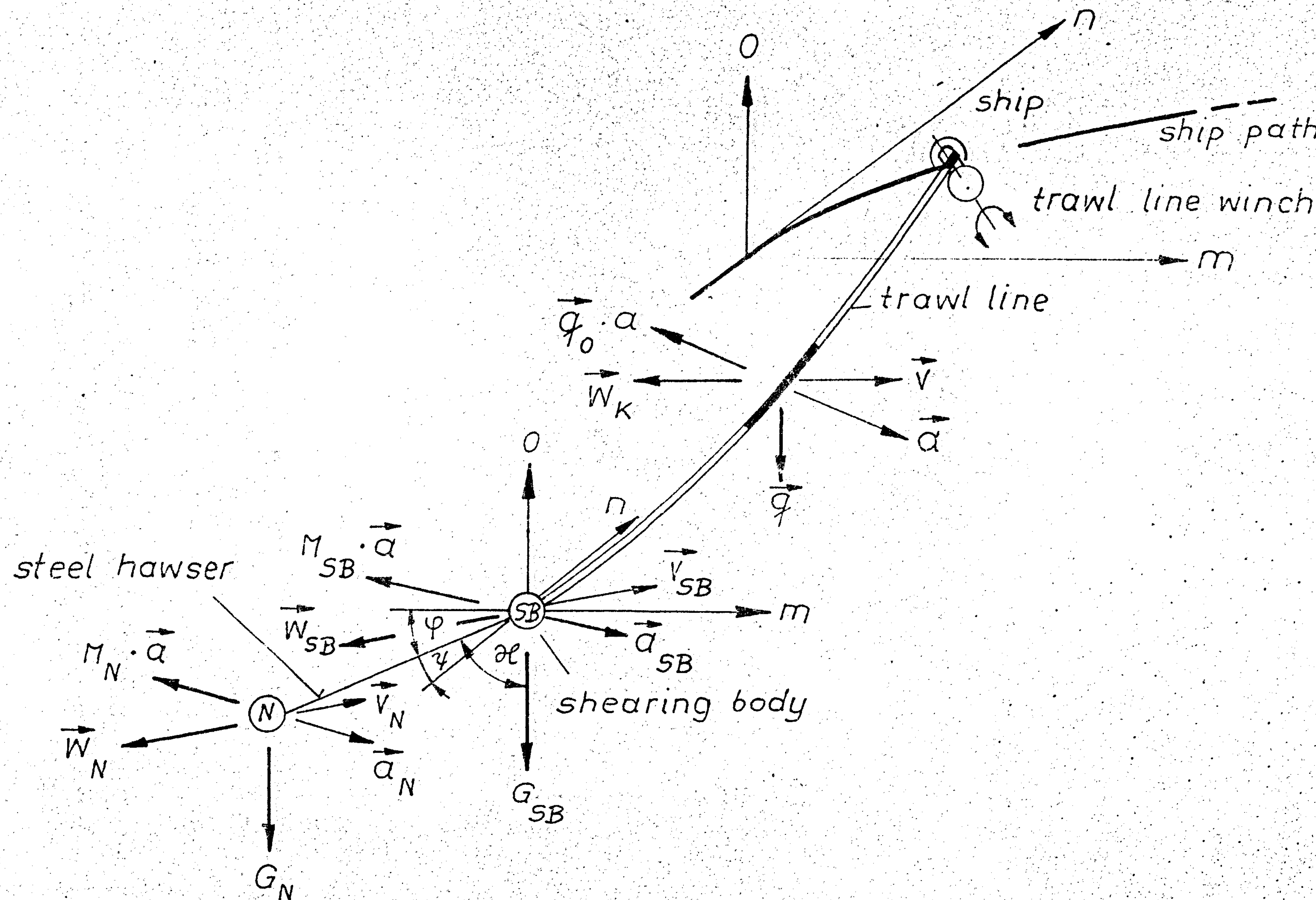

n
0
ship
ship path
trawl line winch
m
trawl line
$\vec{q}_0 \cdot a$
$\vec{W}_K$
$\vec{v}$
$\vec{a}$
0
$\vec{q}$
n
$M_{SB} \cdot \vec{a}$
steel hawser
$\vec{v}_{SB}$
SB
m
$\vec{W}_{SB}$
φ
ψ
ϰ
$\vec{a}_{SB}$
$M_N \cdot \vec{a}$
shearing body
N
$\vec{v}_N$
$\vec{W}_N$
$\vec{a}_N$
G_{SB}
G_N

Fig. 5