SA-2

Abstract to the presentation

Research in fishing technology - state of the art and future tendencies

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1. Fishing gears are complicate technical structures

Both the development and the improvement of fish capturing gears and systems are very complicated processes. Why?

Modern fishing gears like otter trawls are in general systems which consist of netting, ropes, chains and several other elements to influence the buoyancy of headlines, the weight of ground ropes or the horizontal opening of net mouths.

All these net elements are subjected to different kinds of loads. Because of the mechanical flexibility of net and rope systems the shape of fishing gears can be easily changed under the influence of the external forces. But, the assessment of both the external forces and the distribution of loads is very difficult because of the interactions between net structure and fluid.

In case of those fishing gears which come in touch with the sea bed or the water surface the complexity of a mathematical description of the relevant physical phenomena increases, yet.

There is also the fact that there exist interactions between the fishing gear and the living objects, the target species. Therefore the design of the gear and its parameters have to consideration of fish behaviour.

Unfortunately the studies on fish behaviour in the effective zone of fishing gears show fundamental deficits, yet.

That means the development and the use of fish capturing systems raise a lot of questions and problems in different scientific fields like:

1. biophysical and fish-biological problems of fishing,
2. problems of the mechanics of fishing gears,
3. questions of both materials and techniques for gear manufacturing,
4. needs of mechanisation and automation of the fish capture process on board,
5. problems of catch selectivity with regard to fish size and species,
6. problems of stock assessment and management of resources,
7. economic and social problems of the fishermen.

The sequence of the represented questions and tasks is more or less coincidental. Possibly, the problems mentioned above have got a different relevance with respect to people or cultures in different countries of the world. But, generally there is a common realisation that a solution of these tasks requires an international collaboration of different specialists in fishing technology, fishing biology, oceanography just as know how from naval architecture, mechanical and electronic engineering, nautical science, etc.

2. Research profile of the chair "Ocean Engineering" 1 [1)]

The diversity of the scientific subjects and questions mentioned above made a concentration on selected subjects necessary. Our scientific investigations have been focused on the mechanics of fishing gears and related marine systems since 1964 - the year of the foundation of this professorship[2)].

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1 This chair is one of four professorships which built up the Institute for Maritime Systems and Fluid Engineering of the Faculty for Engineering Sciences

2 The first professor and head of the chair was Dr. Harry Stengel.

Both the various tasks and efforts which had to be fulfilled in coherence with the study programme of diploma engineers[3] in fishing technology and the available professorships in other study programmes and the technical equipment were the basis for this profile.
Because of both the structure of the former deep-sea fishing fleet and the long term trawler-production programme of Eastern Germany the scientific investigations were focused on problems of trawl fishery.
The unification of Western and Eastern Germany in 1990 led to a dramatic decrease of the German deep-sea fishing fleet. Therefore we had to extend our study programme but also our field of research activities from subjects of 'pure' fishing technology to those fields like oceanographic engineering, underwater technologies, marine environmental techniques and offshore activities.
But the centre of interest is always the same: modelling and simulation of fluidstructure interactions of complicated flexible technical constructions like rope and netting systems. The investigations are mainly focused on the prediction respectively on the assessment of the dynamical behaviour of loads, tensions, shapes and motions of marine systems acting under the influence of viscous fluids.

3. Results of research

3.1 Preface

Numerical calculations, model tests and full-scale trials are used to assess loads, shapes and motions of fishing gears.
From an ideal point of view full-scale tests would be desirable but expensive and very difficult to perform under controlled conditions. Model tests are therefore needed for basic analyses. A disadvantage of model tests is the difficulty of scaling test results to full-scale results when viscous fluid-dynamic forces compared with weights matter.
The geometrical dimensions and equipment of the model test facilities may also limit the experimental possibilities.
Due to the rapid development of computers with large memory capacity and high computational speed, numerical calculations have played an increasingly role in calculating fishing gears.
Nevertheless fishing gears like pelagic and bottom trawls are characterised by a high number of interactions between the sub-systems, their complexity and the complicated physical phenomena between their flexible structure, the tensions in the net bars, the motions and the distribution of current of the present fluid.
A right rendering of shapes, loads, motions etc. of the original fishing gears through mathematical models demands a precise knowledge of both the most important loads and forces of the original and the principal geometrical relations of the gear in full scale.
Therefore, it is important to stress that numerical computer programmes for fishing gears are also dependent on the development of theories of fluid elasticity.
Of course, it is unrealistic to expect that computer programmes will totally replace model tests in the foreseeable future. The ideal way is to combine model tests with numerical simulations. Therefore the activities of the scientific staff of the chair of Ocean Engineering is characterised by all kinds of research, mathematical modelling, basic studies on physical phenomena in model tests and the validation of numerical analyses in full-scale tests at sea.
But it seems to be a basic law that in the same way how physical models become more and more complicated the necessary effort for mathematical modelling increases, too. This tendency can have some disadvantages especially for an application in practise, yet:

? Some special computer programmes are very expensive. They require both a well educated

3 the downright duration of a diploma study takes five years. The graduate becomes a Diploma Engineer (Dipl.-Ing.) after passing all examinations including the Diploma-Thesis. It is equivalent to the Anglo-Saxon academic degree Master of Science / Master of Engineering Science.

user of the highly sophisticated theory and sufficient computer capacities. Here are definitely first economic obstacles especially for small enterprises.

? So called real-time solutions are the only basis of computer-controlled or computer-aided decisions during navigating or fishing processes onboard. Very complicate computer programmes often cannot fulfil this demand because they are very time consuming.

Therefore much more simple and time saving mathematical tools are also needed for several practical tasks even the exactness of their assessments is lower.

3.2 Selected Results

It is not possible to give an overview of all investigations which were done in the frame of more than 20 doctoral theses, hundreds of Diploma (Master) theses or international projects in the field of fishing technology research in Rostock.

Therefore only some examples of basic and applied research should be given in this paper.

In the early sixties *Harry Stengel* started in Germany to analyse the tensions, the loads and the slack of a rope towed through a viscous fluid. Only some years before Japanese scientists started these investigations, too.

The basic assumptions *Stengel* made were:

1. the rope, wire or twine is a flexible continuum without any stiffness and elasticity,
2. the motion is steady and straight,
3. the hydrodynamic load can be described by Newton's law of comparison, its components drag, lift and transverse force depend on the local angle of attack,
4. drag, lift and transverse force can be taken from model tests,
5. both the winding and the curvature of the middle axis of the rope, wire or twine do not influence the hydrodynamic load,
6. the tension at one side of the rope is known.

The result was a non-linear system of five differential equations of second order. A numerical integration of this equation system by a Runge-Kutta method or others was possible but time consuming because of the low performance of the computer technology at that time.

Now, a lot of calculations had been done for several engineering tasks. Additionally, a so-called trawl-warp-catalogue was edited as a manual for fishermen and designers of fishing gears and towing winches.

But very soon the need for more complicated models was evident to assess for instance the behaviour of stiff but elastic twines or the dynamic motions of ropes.

Nowadays the applications of the computer programmes reach from remotely controlled trawl warps and towed telecommunication cables in marine environment to the behaviour of life ropes in the space when astronauts leave the space station to do their jobs outside.

Another component of flexible structures is netting.

In 1970 *Peter Pretzsch* finished in Germany his studies to a computer-aided design of pelagic trawls. The first computer programme he created was based on the paneltheory. From the mechanical point of view the net panel was regarded as a thin, homogenous and porous skin. Each cross-section of the gear had the shape of a circle. The surface of the panels was mathematically described by the area-theory of the Euklid's Space. Hydrodynamic loads of the meshes, selvage lines, etc. were taken into consideration.

The idea was to find the right cutting rates for four-panel-trawls for a given shape and a known

towing speed of the gear, to calculate the distribution of hanging ratios for a prediction of the hydrodynamic loads, to design the front part of the net (net mouth) and to assess the resistance of the whole net.
In 1977 this method had been extended for pelagic trawls with elliptic cross-sections of linear eccentricity.
The numerical results of these mathematical models were validated by model tests done in a big wind tunnel in the 60-ies and 70-ies.
These solutions led to a so-called first design.
Because every design process is an iterative one the designing engineer is always interested to check the influence of single design-parameters for the whole construction. In such a case a computer programme is needed which allows the calculation of the shape, the load and tensions for a given design.
Theoretical models described before generally are not able to carry out those tasks. A new methodology is needed.
Scientists of several European fishing nations like France, Iceland, Norway and the United Kingdom have started for ten to twenty years to use the method of finite elements (FEM) for the calculation of pelagic trawls. They did it with different success.
In Rostock *Hartmut Leitzke* analysed the possibilities of an introduction of FEM into net design in the beginning of the 80-ies because this method is a very power-full and world-wide used one in several fields of mechanical and civil engineering.
He recognized that the high flexibility of rope and net systems like fishing gears especially if the tensions in the mesh bars are low - need several restrictions and assumptions which are not useful from the view point of physics. Therefore he modified this method and created a so-called Tension-Element-Method (TEM) for flexible rope and net constructions. Based on this theory *Gerd Niedzwiedz* and others created and tested a power-full computer package - the Rope Net Calculator.
This programme includes a self programming tool of all necessary equations for a rope-net-system; its design has to be described by a graphic editor. Additional gear elements like buoyancy balls, flexible kites, weights, etc. and special characteristics of the material applied, hydrodynamic coefficients, etc. can be integrated into the mathematical model. A PC of an average performance need for an automatic equation formation of a gear consisting of about 32,000 elements approximately 20 minutes. The calculation of such a gear system can be very time consuming (up to several hours).
Because of the high reliability of the Rope-Net-Calculator we have already checked several trawl designs of international net making firms.
Different studies on the influence of the sea bed on bottom trawls are already known. We were interested in getting more basic knowledge in the physics of drag of bottom trawls. The friction between netting and soil is widely unknown.
Therefore we created special facilities to do the necessary model tests. At first we investigated several types of cylinders with a different diameter-weight ratio, with a different quality of surface and with a different towing speed. Later wires, chains and other trawl elements had been tested.
We could observe that the drag of each investigated element has got three shares. These are friction, hydrodynamic load and the drag of the soil moved by the ground rope, the bobbins or the chains of the gear. Friction depends on the weight of the element in water and the coefficient of friction (Coulomb's law of friction). The hydrodynamic load depends on the shape of element and the relative velocity in water (Newton's law of comparison). The drag of moved soil especially depends on the steady load of the element by its own weight and the towing speed against the bottom (like Froude's law of constants). We could quantify the relation between drag, steady load of the element and its depth of penetration into the sediment.

These studies made it possible to model and to simulate the interactions between bottom trawls and the sea bed by mathematical investigations, by model tests and full-scale measurements to reduce the necessary performance for trawling and to reduce the impact of the gears on the marine environment. The fishermen are interested in using such fishing gears which make it possible for them to catch the national and international fish quotas efficiently. On the other hand they are also interested in getting a minimum of by-catch and juvenile fish.

The fishermen have recognised that their own marine resources are very limited and they have also recognised the necessity to manage the stocks. For that reason one essential aim of research activities in fishing technology is the further increase in selectivity of trawls by useful and inexpencive facilities.
Selectivity of trawls is a question of the local hydrodynamic conditions inside of the gear, too, so the conviction of several European fishing technologists.
If that is true - and I am sure that it is - it should be useful to analyse the distribution of current and pressure of the fluid inside and around pelagic trawls.
We started basic investigations. At first model tests were carried out with 9 different netting cones in a towing tank. Following parameters of the netting cone were varied:

? the opening angle of the netting cone;
? the number of meshes;
? the hydrodynamic transparency (100%, 50%, 0%) of that area which represents the cod end;
? the towing speed.

Following tendencies during the tests were observed:

? the opening of the netting cone is really important for the distribution of current and pressure inside and around the net cone;
? a smaller opening angle of the netting cone leads to significant changes in the distribution of velocity and pressure;
? close to the netting plane the pressure decreased in radial direction to the cone axis in each case;
? a different hydrodynamic transparency does not influence the current close to the opening of the cone.

Additional tests were carried out with models of different cod-ends of trawls in a wind tunnel. The scale was 1:2. The results of the net cone tests were confirmed.

3. Final remarks
The author outlined only some remarks and scientific results of the research work of the Chair of Ocean Engineering of the University of Rostock in the field of mechanics of fishing gears.
The main aim of the investigations is to do basic research to understand the physical phenomena of flexible rope and netting systems like trawls. The knowledge about the relevant interactions between structure, fluid and living object is the key for a sustainable development of the fishery.