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ANALYSIS OF THE CONSTRUCTION AND RESISTANCE OF PELAGIC TRAWLS FOR CATCHING PILCHARD IN THE ADRIATIC BASED ON THE MODEL TEST AND UNDERWATER OBSERVATIONS

ANALIZA KONSTRUKCIJA I OTPORA LEBDEĆIH KOČA ZA ULOV SRDELE U JADRANU NA TEMELJU ISPITIVANJA MODELA I PODVODNIH PROMATRANJA

Perica Cetinić[1] and Jozef Swiniarski[2]

[1] *Institut of Oceanography and Fisheries, Split*

[2] *Faculty of Sea Fishery and Nutrition Technology, Institut of Aquiculture and Fishing Technique, Szczezecin*

The paper gives an analysis of the results of testing the construction and resistance of the pelagic trawl models designed for catching pilchard and other species of the small pelagic fish in the Adriatic. The tested models are made in four variants differing in the constructional elements of the mouth of the gear, while the other parts of the tested nets were equal in construction. The tests were conducted by trawling the models by means of the measuring bridge on the catamaran and the research ship. During these tests the constructional and technical parameters of the gear were determined and on this basis also the best constructions of the nets for catching pilchard were designed.

1. INTRODUCTION

1.1. General description of the problem

The Yugoslav sea fishery is based mainly on the catches of pilchard and other small pelagic species. For catching these species the basic fishing gear is the purse seine. The fishing vessels in the formation of the Yugoslav fishing fleet are meant, primarily, for seining.[1]) They are rather old vessels with small power of their main driving engines. Although seining is very frequent in the saltwater fishery, still, trawling is predominant. Over 60% of the world catches are achieved by trawls, thanks to their efficiency and universality. These fishing gears are used in catching almost all the benthic and pelagic fish species and other sea organisms. The growing interest of

[1]) Recently new fishing units constructed for fishing with trawls have been introduced into the formation of the Yugoslav fishing fleet.

the Yugoslav saltwater fishery requires the usage of trawls, particularly pelagic trawls meant for catching pilchard and other species of small pelagic fish.

To make fishing more efficient, it is necessary to have fishing gears adapted to the technical parameters of the fishing units, fishing regions, and to specific life and behaviour of the caught fish species and other sea animals, which change and move continuously. The fishing vessel and fishing gear should be treated as a closely linked (undivided) fishing complex.

The basic requirement for the fishability of the fishing complex[2]) is its precise construction and exploitation of the fishing gear in order to be adapted optimally to the technical parameters of the fishing vessel and fishing situation.

The catches of pilchard and other small pelagic species play a decisive role in the Yugoslav sea fishery. The best proof of their significance in the total Yugoslav catch of seafish is their quantity fluctuating between 70—75% for several years. Still, the basic fish species caught in the Yugoslav sea fishery is the pilchard. For the last several years its presence in the catch has been 52% on the average.

Thanks to the catch of the small pelagic fish a strong fish processing industry has been developing on the Yugoslav coast. Its basic raw material is pilchard, therefore the whole fish processing industry is mainly directed to processing this species of fish. This fact shows how much the Yugoslav sea fishery is interested in the small pelagic fish catches, pilchard in particular, and in the promotion of the technique and new efficient fishing gear for catching it.

In 1944 Larsen from Skagen, Denmark, constructed the first four-sided pelagic trawl. Most of the later prototyper of the pelagic trawls, travled by one or two trawling boats, are basically similar in construction to Larsen's pelagic trawls.

The exploitation of the small pelagic fish in dispersed shoals and with stronger reactions to external impulses requires larger fishing gears, and also of better hydrodynamic characteristics. As regards the construction of the trawling fishing gear, especially of the pelagic trawls, using one trawling vessel, the above situation requires, first of all, reduced resistance characteristics of the gear in order to speed up trawling. This aim has been realized by using low resistance net material (netting with large meshsize), and by constructing nets with a smaller angle of attach of the netting in its elements. As the trawling speed is an important factor in using pelagic trawls successfully, the trawlers with the main driving engines of little power cannot use these gears successfuly for catching the rapid species of fish and those that react strongly to the fishing gear. The trawls dragged by such trawlers have a small opening of the mouth, i. e. of penetration, therefore the fishing capabilities of such a gear are insignificant and the fishing productivity[3]) of such trawlers is very low. In this case the size of the gear (mouth) is to be enlarged and dragged by means of two vessels and so achieve the needed trawling speed indispensable for catching certain species of fish.

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[2]) The fishing complex consists of the fishing vessel and trawl system. The latter consists of the actual fishing gear (trawl), spreading device and the elements connecting the ship with the fishing gear.

[3]) The fishing productivity is the quantity of the caught fish (size of the catch) realized per fishing unit (fishing vessel) in a definite unit of time.

A further improvement in the development of the pelagic trawl is the construction of trawls with ropes. On the trawl with ropes the front of the gear, that was formerly made of netting with large meshsize, has been replaced by a system of ropes that connect the head, lead and side ropes with the net part of the belly of the trawl. Nowadays such solutions are used successfully when manufacturing trawl fishing gear, the pelagic trawl in particular, using one or two trawling boats.

As in the past the catches of pilchard and other species of small pelagic fish by means of purse seines, under the Yugoslav conditions, was not efficient enough and the results could not satisfy, time has come to replace this method of fishing by a finer, more universal and more productive gear, namely by pelagic trawls. Under our conditions the pelagic trawl exceeds the purse seine because:

— pelagic trawl fishing depends less on the weather conditions;
— it ensures a greater number of fishing days and so also a greater productivity of the catch;
— it makes it possible to supply industry and markets more evenly with raw material and it eliminates the »peaks« in fishing, which was often the case with the earlier method of fishing (purse seining), manifested by a single catch of great quantities of fish which the processing industry was not capable to process and preserve;
— the fishing technique is more reliable and simple and this makes catching possible by day and night, even under worsened atmospheric conditions;
— cheaper fishing gear is used and a smaller number of the ship's crew per vessel is employed.

Practical application and selection of suitable construction solutions of the pelagic trawls, by using one or two vessels for catching pilchard and other species of the small pelagic fish in the Adriatic, should be adapted to the characteristics of the fishing units meant for this kind of fishing. The earlier fishing vessels exploited in the Yugoslav Adriatic fishing were, in the first place, meant for seining, and few of them were employed, either periodically or permanently, in fishing with trawl fishing gear applying the bottom trawls.

Tests with pelagic trawls for catching pilchard and other small pelagic fish in the Adriatic by means of one or two trawling boats have shown that the basic prerequisite for catching pilchard is to achieve adequate speed of trawling, which has to be over 4 knots (Grubišić 1970, Cetinić 1972, 1974 and 1976). This has also been proved by the tests conducted by Korotkov and Kuzmin (1972) for the catches of horse macherel, sardine, herring and mackerel. By basing it on direct underwater observations they have found that when the trawling speed is below 4.5—4.6 knots these species react by swimming ahead of the month of the trawl, even escaping from the cod end.

The preliminary tests in the Adriatic have shown that the mentioned rates of speed of trawling cannot be attained with pelagic trawls by using one trawling boat of 300 HP engine power. Therefore the vessels with the main driving engines of small power cannot practically and efficiently use the pelagic trawl for catching pilchard with one trawler. This is possible with the pelagic trawl dragged by two trawling boats (Cetinić 1972, 1974). It should be pointed out that when catching with pelagic trawls with one vessel the ship's engine and propeller cause noises which scare fish away, especially when fishing in smaller depths. However, when catching with pelagic trawls using two vessels such noises can have a positive effect, because they concentrate fish within the space between the two trawlings boats, i. e. within the space penetrated by the fishing gear. Tests in the Adriatic with the pelagic trawl for catching pilchard using one vessel have shown that the noises of the ship's engine and propeller in shallow fishing regions have a negative influence on the results of the catch (Cetinić, 1974). These are the reasons why all the tests should be directed to the practical application of the pelagic trawl for catching pilchard by means of to trawling boats. The problem is to design such pelagic trawls chose construction, size, and resistance in the first place, will optimally adapt then to the trawling capabilities of the fishing units meant for fishing with pelagic trawls, and which will ensure the trawling speed of over 4 knots.

Several are the ways of judging the advantages of the trawling fishing gear. One of these ways is based on comparing the results of the catch attained with the tested gear in the same or almost the same fishing regions, the other is based on long-term testing of one or more fishing units applying the tested gear under the conditions of industrial fishing. Other ways are based on the technical test at which the basic linear-driving parameters characteristic for the technoconstructural characteristics of the tested fishing gear are determined. Technical tests can be conducted on the actual gears and their models.

Actual tests are carried out on the full scale gear using the corresponding vessel which the tested gear is meant for. As the control-measurement instrument is being used and the needed vessel withdrawn from regular exploitation such tests are rather expensive. Besides, under actual conditions it is hard to follow up the gear and the whole fishing system directly, and also the comparability of the conditions of testing. Therefore models of the fishing gear are increasingly used in tests. In relation to the full size gear the models are made in reduced scale. Models are tested in various branches of modern technique, for example in aeronautics, shipbuilding, applied hydrolics, etc. Models are largely used in testing fishing gears. Countries with well developed fishing industry have attained great success in this line: Japan, German Federal Republic, German Democratic Republic, France, USSR, UK, Canada, Poland, and some other countries.

Model test in very important for improving and designing the fishing gear, because this makes it possible to check it shorter time engaging fewer facilities. At these tests it is possible to observe directly the gear or its elements during operation, which makes it possible to learn about the preliminary characteristics of the gear under testing. These tests make it possible to objectively assess the advantages and disadvantages of the new constructional solutions, and, in a relatively short time, to check a series of variations of the gear under test.

The fishing gear can be tested by using the following facilities:

— tunnels, basins and hydrodynamic canals,
— wind tunnels,
— experimental polygons on rivers, lakes and coastal sea-waters,
— reserarch and industrial vessels for conductiong tests under natural conditions in the fishing grounds.

The kind and scope of the fishing gear model test depend on the technical basis and available facilities. The models tested in tunnels and basins are made in a smaller scale, while the models tested on the water trackways and polygons are made in a large scale.

The aim of testing is the analysis of the construction and resistance of the pelagic trawl models designed for catching pilchard in the Adriatic. The tests involved:

— measurement of the vertical and horizontal spread of the mouth of the pelagic trawl belly;
— measurement of the shape of the mesh in each individual element of the pelagic trawl;
— measurement of the resistance of the analysed pelagic trawl models;
— determination of the dependences among the trawling speed, form of the mouth of the trawl belly, coefficient of the mesh spread and pelagic trawl resistance;
— underwater observations and photographic documentation of the shaping of individual construction elements of the analysed trawls;
— finding out the most suitable constructional solutions for the pelagic trawl designed for catching pilchard in shallower fishing regions.

1.2. Study of the problems based on the current state in literature

Many positive characteristics of the model test technique have resulted lately, in the world fishery, in a rapid development of the model fishing gear tests, of the pelagic trawl in particular.

Teh first tests of the fishing gear models were carried out in USSR by Šorigin in the thirties (Fridman, 1964). These tests, whose aim was to determine the mechanics of the trawl, were carried out in the experimental basin on the large scale and reduced scale models, which were constructed in the 1:4 or 1:26—1:35 scale. As all the requirements of mechanical similitude between the model and the original were not met the results of the tests of the model did not completely correspond to some results obtained at testing the full scale gear nor to the data from fishery practice (Fridman, 1964).

Fridman (1957, 1964, 1969 and 1973) conducted tests of the trawl model and of a piece of large scale netting. These tests were conducted in the wind tunnels and on the models made in 1:15 scale, which met the requirements of the geosim model. The basic purpose of this test was to determine the mechanics of the trawl. Respecting exactly the conditions of mechanical similitude it was possible to abtain a greater concordance between the results obtained at testing the model and the full scale gear, so no deviations between the results of the model and the actual gear tests were noticed, as it was the case in the tests conducted by Šorigin (Fridman, 1964).

In the USSR Alijev and Baranov (Fridman, 1964) also tested the trawl model.

In the DRG the model tests were also used. The works by Stengel and Fischer (1964, 1966) have to be particularly mentioned. They tested the 1:10 scale trawl model and a piece of netting in the wind tunnel. The basic aim of these tests was to determine the coeffiicient of the hydrodynamic resistance indispensable for the theoretic design of the trawl. Pretzsch (1970) also studied these problems.

Special attention deserve the tests carried out by Dickson (1959) on the 65,5 feet trawl model for herring catches. These tests were conducted on the waterway track. In this test it was essential to find out the most optimal scale for making a model relative to the full scale gear, and to evaluate the constructional parameters of the tested gear. The tested model was made in 1:8 scale, and the twine diameter and size of the mesh in 1:4 scale.

Schärfe (1966) tested the models of the bottom and pelagic trawls, and the combined bottom-pelagic trawls made in a larger scale. The aim of these tests was to check the construction and rigging of the full scale gear, and also the whole fishing complex and the basic technical parameters. The models were made in 1:4 scale, and the tests were conducted on the sea polygons. The tests included direct underwater observations and underwater photographing made by divers.

French scientists in Boulogne also tested the fishing gear models in small scales fixed in the basin with running water (Nedelec, Portier, Libert, 1973). Tests were conducted with the bottom and above-bottom trawl models constructed in 1:20 scale, and with the pelagic trawl models constructed in 1:15 scale. The models were used for checking the correctness of the fishing complex construction of the actual gear in exploitation.

In Japan the fishing gear models are frequently tested. In the thirties of this century Tauti (Kawakami, 1959, 1964) were engaged in the principles of modelling. Kawakami (1964) was also engaged in the theory of the model test. According to him the scale of the models should not go over 1:20. In Japan the first tests of the fishing gear model were conducted under laboratory conditions in a basin with circulating water (Takayama & Koyama, 1959). Takayama and Koyama tested the influence of the kite on the spread of the trawl. The trawl models were made of cotton twine in 1:30 scale.

Tests of the fishing gear models were also conducted in Poland. Recently the test technique has been developing more intensively, so that for this purpose on the Faculty of the Sea Fishery and Technology of Nutrition in Szczecin the Station for Model Test has been instituted and equipped with special facilities adapted for these tests. Ziecik & Kwidzinski (1966) tested the bottom and pelagic trawl models in 1:4 and 1:8 scales. Tests were carried out on the waterway track in the lake. The aim of these tests was to find out regular and the most useful methods for modelling the basic technical parameters and the interdependence between the models and the full scale gear. In the Institute of Aquiculture and Fishing Technique of the Faculty of the Sea Fishery ang Technology of Nutrition in Szczecin in 1975 and 1976 tests were conducted on a set of pelagic trawl models used by the vessels of industrial fishery. These tests were conducted to measure resistance and to determine the basic constructional parameters of the gear, and also to conduct direct underwater observations and photographing. Richert (1971, 1972) and Bucki (1971) also tested the fishing gear models on the polygons under sea conditions. Richert conducted structural tests of the pelagic trawls to obtain data for optimalizing their constrution, while Bucki conducted tests with the bottom trawl models to evaluate their technical and catching characteristics. Ziembo (1976) conducted analyses of the water flow velocity through the bottom trawls by basing it on the model test. Tests were conducted with the models constructed in 1:4 scale, and with the full scale trawls. Czajka (1976, 1977) also conducted series of tests with the bottom trawl models.

2. TEST MATERIAL AND METHOD

2.1. Theoretical bases for model tests

The principle of modelling the fishing gear, similar to the modelling of other technical constructions, is based on the theory of mechanical similitude. On this basis it is possible to carry out calculations of the results obtained by testing the model on the analogous phenomena (manifestations) in the full scale gear. Two physical phenomena (one full scale, the other a model) subjected to the same mechanical effect are physically similar if the values obtained by model test and multiplied by the constant coefficients, called the model scales or similitude coefficients, give the same values as are those obtained by testing the full scale gear. In this sense conditions that ensure similitude of both phenomena, namely the model and the full scale gear, are to be fulfilled. In model test the following conditions are to be ensured:

— geometrical similitudes

— kinematic similitudes

— dynamic similitudes.

The basic principle is to ensure the conditions of the geometrical similitude that means the fulfillment of these linear dimensions:

$$\frac{l'}{l} = C_l \qquad \alpha' = \alpha \tag{1}$$

l = the characteristic linear dimension of the gear (m),

C_l = the coefficient (scale) of the linear similitude,

α = the angle between the corresponding ropes

The symbols with the apostrophe refer to the model.

Analogous to these values the ratio of the surface and volume of the model and the full scale gear is:

$$\frac{A'}{A} = \frac{l'^2}{l^2} = C_l^2 \tag{2}$$

$$\frac{V'}{V} = \frac{l'^3}{l^3} = C_l^3$$

A = the surface of the gear (m^2)
V = the volume of the gear (m^3).

In the fishing technique many problems may be examined using the static similitude which requires the fulfillment of the force, besides the linear dimension. This means the fulfillment of these equalities:

$$\frac{l'}{l} = C_l; \qquad \alpha' = \alpha; \qquad \frac{R'}{R} = C_R \tag{3}$$

R = active force affecting the gear (kG),
C_R = coefficient (scale) of the force similitude.

Kinematic similitude means the fulfillment of two conditions, namely the linear dimension and time, and is expressed in the dependencies:

$$\frac{l'}{l} = C_l; \qquad \frac{t'}{t} = C_t \tag{4}$$

t = time characterized by the movement of the fishing gear (sec.),
C_t = coefficient (scale) of time similitude.

Dynamic similitude means the fulfillment of three conditions: length, time, force. This similitude is fulfilled when the corresponding forces are in the same relations. It is expressed by:

$$\frac{l'}{l} = C_l; \qquad \frac{t'}{t} = C_t; \qquad \frac{R'}{R} = C_R \tag{5}$$

The above requirements refer also to the fishing gear. Due to their specific qualities expressed first of all in the elasticity of their construction, these requirements should be adapted to the specific characteristics of the fishing gear.

Fridman (1969), having in mind the previously presented theoretic requirements and also the results of his own researches, has formulated the following requirements to ensure the similitude of the fishing gear:

$$\frac{a'}{l'} = \frac{a}{l} \quad \text{or} \quad \frac{a}{l} = \text{idem},$$

$$\frac{d'}{l'} = \frac{d}{l} \quad \text{or} \quad \frac{d}{l} = \text{idem}.$$

As $\frac{d}{l} : \frac{a}{l} = \frac{d}{a}$, the condition of similitude follows:

$$\frac{d'}{a'} = \frac{d}{a} \quad \text{or} \quad \frac{d}{a} = \text{idem},$$

$$\frac{k}{d} = \frac{k'}{d'} \quad \text{or} \quad \frac{k}{d} = \text{idem},$$

$$u_1 = u'_1 \quad \text{or} \quad u_1 = \text{idem},$$

$$u_2 = u'_2 \quad \text{or} \quad u_2 = \text{idem},$$

$$\varepsilon = \varepsilon' \quad \text{or} \quad \varepsilon = \text{idem}. \tag{6}$$

$$R_e = \frac{lv}{\nu} = \frac{l'v'}{\nu'} \text{ or } \frac{lv}{\nu} = \text{idem}, \tag{7}$$

which denotes Reynolds number of similitude.

$$F_r = \frac{v^2}{gl} = \frac{v'^2}{g'l'} \text{ or } \frac{v^2}{gl} = \text{idem}, \tag{8}$$

which denotes Froud's number of similitude.

$$N_e = \frac{R}{\varrho_w l^2 v^2} = \frac{R'}{\varrho'_w l'^2 v'^2} \text{ or } \frac{R}{\varrho_w l^2 v^2} = \text{idem}, \tag{9}$$

which denotes Newton number of similitude.

$$S_h = \frac{vt}{l} = \frac{v't'}{l'} = \frac{vt}{l} = \text{idem}, \tag{10}$$

which denotes Struhal number of similitude.

$$W_e = \frac{\alpha t}{\varrho_w l v^2} = \frac{\alpha' t'}{\varrho'_w l' v'^2} \text{ or } \frac{\alpha t}{\varrho_w l v^2} = \text{idem}, \tag{11}$$

which denotes Weber number of similitude.

$$M_a = \frac{v}{v_d} = \frac{v'}{v'_d} \text{ or } \frac{v}{v_d} = \text{idem,} \tag{12}$$

which denotes Mah's number of similitude.

Where:

a = is the value of one side of the netting mesh (mm),
d = diameter of the twine of the netting (mm),
k = relative roughness of the surface of the twine,
u_1, u_2 = coefficient of the hanging netting,
ε = coefficient of relative deformation,
R_e = Reynolds umber of similitude,
V = coefficient of kinematic viscosity (m^2/s), which represents the viscosity and specific thickness of the environment,
v = movement speed (trawling) of the fishing gear,
F_r = Froude's number of similitude,
g = dropping acceleration (m/s^2),
N_e = Newton's number of similitude,
ϱ_w = specific density of water (kGs^2/m^4),
S_h = Struhal's number of similitude,
W_e = Weber's number of similitude,
α_t = coefficient of surface tension (kG/m^2),
M_a = Mah's number of similitude,
v_d = sound velocity (m/s).

It is technically difficult and practically impossible to fulfil all the conditions of similitude for the fishing gear. For this reason when testing the fishing gear models we use approximate similitude resulting from the specific qualities of the fishing gear constructions. However, the results obtained by testing the fishing gear models are relevant to practical purposes to characterize the phenomena in the full scale gear.

The pelagic trawl will serve as the specimen for considering in detail the fulfilment of the individual conditions of similitude.

The condition $\frac{d}{a}$ = idem is hard enough to fulfil because the linear dimensions (e. g. length) of the pelagic trawl are several times bigger than the meshsize. This condition is hard to fulfil when the reduced scale models are constructed, especially the pelagic trawls for catching pilchard and other species of the small pelagic fish, because in the Adriatic one side of the mesh must be 8—10 mm in the cod end of the full scale gear.

When testing the fishing gear model the condition $\frac{d}{a}$ = idem can be fulfilled in the following way:

— by selecting for the model the twine of suitable diameter and the sizes of one side of the meshes that result from the scale of the model in relation to the full scale gear. For technical reasons, however, it is not always possible to fulfil this condition;

— by using the same net material for both the model and the full scale gear.

If there is a great difference of the twine thickness between the full scale gear and its model, then also differences in the value of Reynolds number can appear. In this connection, according to Fridman (Bucki, 1971, Swiniarski, Krepa, 1975), to realize the condition $\frac{d}{a}$ it is necessary to construct both the model and the full scale gear using the same net material (d = d') and preserve the condition $\frac{d}{a}$ = idem. In this case also the condition $\frac{k}{a}$ = idem will be fulfilled.

The fulfilment of the condition u_1 = idem and u_2 = idem does not present any problem and is completely feasible because it refers to the coefficients of the hanging netting which are the same in the model and the full scale gear.

Reynolds number, which represents the inertial force and viscosity relationship, is dimension less and it denotes the characteristics of the flow. It is hard to realize the fulfilment of the condition Re = idem at modelling the fishing gear. If the characteristic linear dimension — 1 in Reynolds number $Re = \frac{1v}{\nu}$ = idem is substituted by the characteristic thickness — d, then the condition Re = idem gets this content:

$$Re = \frac{dv}{\nu} = \frac{d'v'}{\nu'} = \text{idem} \tag{13}$$

Considering that d = d' (model and full scale gear are made of the same net material), at $\nu = \nu'$ (tests were conducted in similar environments), to ensure the same Reynolds number v should be equal to v', which means that the model must be trawled at the same speed as the full scale gear is. However, in practice this is hard to realize. It follows that in practice it is not possible to fulfil the similarity condition according to Reynolds rule.

Nedelec and Portier (1973) took the value of the kinematic viscosity coefficient $\nu = 1.31 \times 10^{-6}$ m²/s. when testing the bottom and pelagic trawl models. For practical purposes they took the identical value of that coeficient for both fresh annd salt water.

According to Stengel's test (1964) conducted in the wind tunnel, the resistance of the flat netting does not depend on Reynolds number when its value is within the 10^3 to 10^4 range.

Fridman (1967) also alleges that the resistance coefficient of the netting depends to a small degree on Raynolds number when its value is within the 3×10^2 to 7×10^3 range. It follows that in case of trawl modelling, Re = idem has no decisive influence.

Froud number, which represents the relationship between the inertion and gravity forces, is also dimensionless and it serves for determining the speed of trawling the model. Froud number of similitude can be written in the following form (Bucki, Pietkiewicz, 1973):

$$Fr = \frac{\mu v^2}{\gamma_1 l} = \frac{\mu' v'^2}{\gamma'_1 l'} \tag{14}$$

on the assumption that the model and the full scale gear work in the same enviroment and that the model and the full scale gear are made of the same material (the same synthetic fibre), i.e.

$\mu = \mu'$ — the same environmental viscosity,

$\gamma_1 = \gamma'_1$ — the same specific weight of the net material.

By altering the quoted form of Froud number the formula for the speed of trawling the model is obtained:

$$v' = v \sqrt{\frac{l'}{l}} \text{ for } Fr = \text{idem.} \tag{15}$$

Nowton number, which represents the dimensionless coefficient of the lift force, should be the same for the model and the full scale gear. Newton number of similitude can be expressed by:

$$Ne = \frac{R}{\mu l^2 v^2} = \frac{R'}{\mu' l'^2 v'^2} \tag{16}$$

Considering that $\mu = \mu'$ even after the alteration of the quoted formula, the formula that determines the resistance of the model (force) is obtained:

$$R' = R \frac{l'^2 v'^2}{l^2 v^2} \text{ for } Ne = \text{idem.} \tag{17}$$

Keeping the similitudes by Struhal, Weber and Mah, at modelling the fishing gear, has no particular significance.

The condition Sh = idem should be kept at modelling the unstable processes. As the pelagic trawls in determined periods of time are trawled at constant speed the condition Sh = idem has no greater significance and it can be neglected.

Mah condition of similitude, according to Praudtl (Scharping, 1973), has no significance if $Ma < 0.5$. At the trawling speed 2.5 m/s, $Ma \leqslant 0.5$. As trawling of the fishing gear is done at a speed lower than 2.5 m/s, Mah number of similitude has no essential significance.

Weber condition of similitude should be present when the object is moved on the water's surface. As the pelagic trawl is not on the water's surface during trawling this condition of similitude does not influence the work of the trawl.

2.2. Principles of model construction

A very important problem at testing the model is to determine the scale, namely to determine the size of the C_1 relation. Experts'opinions differ in this case. Kawakami (1964) thinks that the models should not be constructed in the scale larger than 1 : 20, while Dickson (1959), on the basis of his own tests of the trawling fishing gear model, thinks that the scale 1 : 4 is the most optimal because a larger one does not give enough precise results.

Bucki and Pietkiewicz (1973) consider that the models should not be constructed in a too small scale. According to these authors the models should be made in the scale from 1 : 3 to 1 : 6. Such a scale makes the construction of the model easier and it ensures exact measurement of individual parameters of the model.

The scale $C_1 = \frac{1}{2}$ to $\frac{1}{25}$ is most frequently applied for testing the trawl models (Swiniarski, Krepa, 1975). According to these authors, the models should be constructed of the same material as the full scale gear is. Also, the model and the full scale gear must have identical knots and similar elasticity, which will make it possible to ensure high hydrodynamic similitudes.

The tested pelagic trawl models, as presented in this work, were made in the 1 : 2 scale. This means that all the linear dimensions, or length and breadth of each individual net element, dimnesions of the boundary ropes (head rope, foot rope, side ropes, wing ropes, etc.), meshsize, twine and boundary ropes diameters are reduced twice. The number of the meshes in the model is the same as in the full scale gear, but the meshsize is reduced twice. The cycles of cutting the netting of individual parts of the model are the same as in the analogous elements of the full scale gear. The coeffieients of the hanging netting on the ropes are also the same as in the full scale gear. The linear elements of the trawling complex rigging of the pelagic trawl model and their thickness are also made in 1 : 2 scale.

In accordance with the presented principles, the scale of geometric similitude of the tested models in this paper are:

$$C_1 = \frac{1}{2}; \quad \frac{d}{a} = \text{idem}; \quad \frac{a}{1} = \text{idem};$$

$$u_1 = \text{idem}; \quad u_2 = \text{idem};$$

$$\frac{d'_1}{d_1} = \frac{1}{2}; \qquad \frac{b'd_1}{bd_1} = \frac{1}{2};$$

where:

d_1 = rope diameter (mm)

bd_1 = breadth (thickness) of the elements of the fishing gear rigging (mm), as the otter boards, kites, main weights, etc.

The speed rate of trawling the model, when the speed of trawling the full scale gear is known, and vice versa, is calculated from Froud number of similitude on the basis of the following formula:

$$v' = v\sqrt{\frac{l'}{l}}$$

The trawling speed of the models constructed in $\frac{1}{2}$ scale is presented as:

$$v' = v\sqrt{\frac{1}{2}}$$

$$v' = 0.70701\ v$$

Knowing the trawling speed of the model constructed in 1 : 2 scale, the trawling speed of the full scale gear is determined in the following way:

$$v = \sqrt{\frac{1}{2}}$$

$$v = \frac{v'}{0.70701}$$

2.3. Subject matter of the research work

The subject of this research is the pelagic trawl 32/37 × 17/22, designed for catching pilchard and other small pelagic fish species in the Adriatic. The researches were conducted on the models of this net constructed in 1 : 2 scale. The models of the tested pelagic trawls were constructed in four variants that differed in the construction of the elements of the mouth of the gear. The construction of the tested variants of the models was the same from the second segment of the belly towards the cod end, and all the alterations were made on the wings and the first segment of the belly. All the models were constructed from polyamide netting, differing in the construction of the cod end which was made of knotless and, the other parts of the gear, of knotted netting.

Fig. 1. is the scheme of the variant 1 model. From the viewpoint of construction it is identical with the full scale gear and it serves as the original construction for all the other models to be tested. Therefore the figures

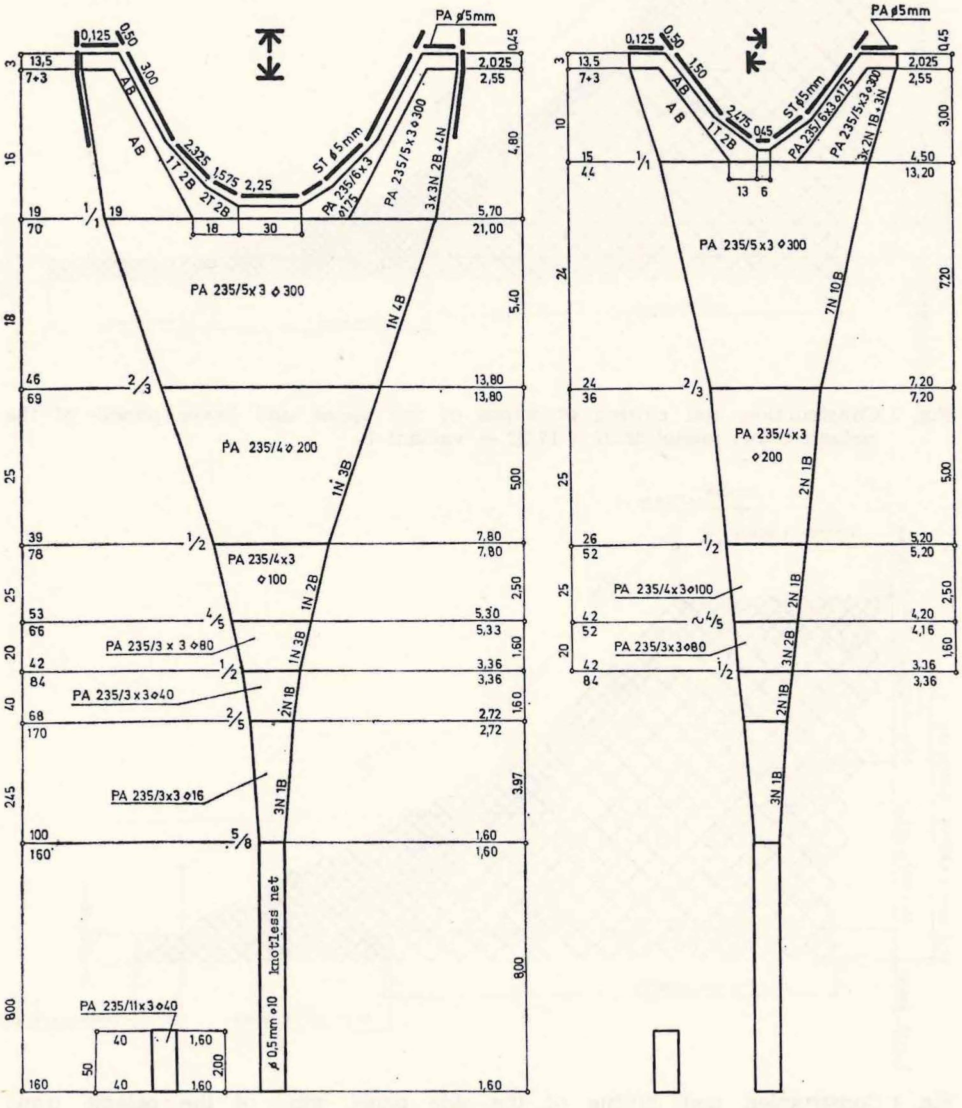


Fig. 1 Pelagic trawl model 32/37 × 17/22 in 1 : 2 scale — variant 1.

2 & 3 show the detailed schematic presentation of the construction of the mouth parts of that model and also the top, lower and side wings, wedges and their lengthenings, the wing parts and the bosom of the gear. The outer

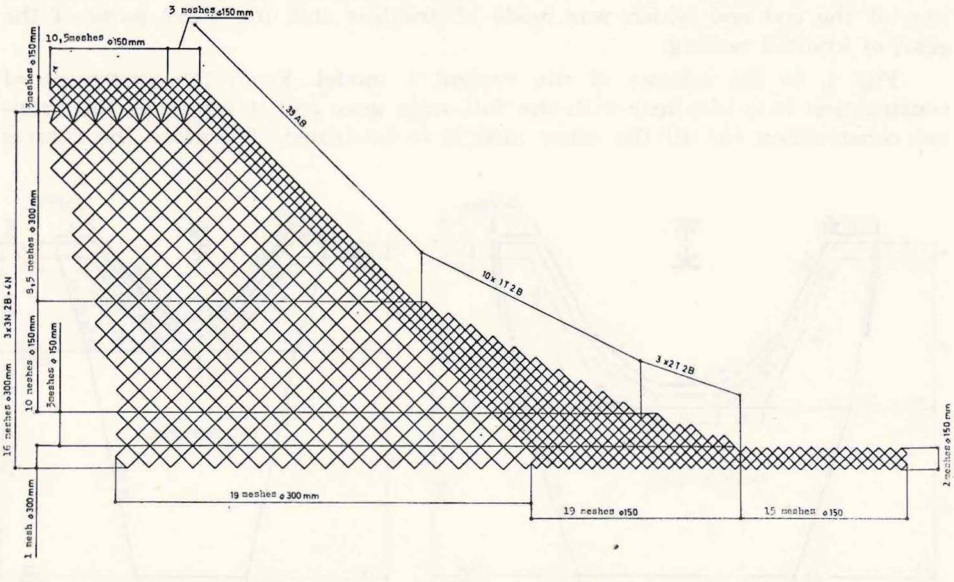


Fig. 2 Construction and cutting of wings of the upper and lower panels of the pelagic trawl model 32/37 × 17/22 — variant 1.

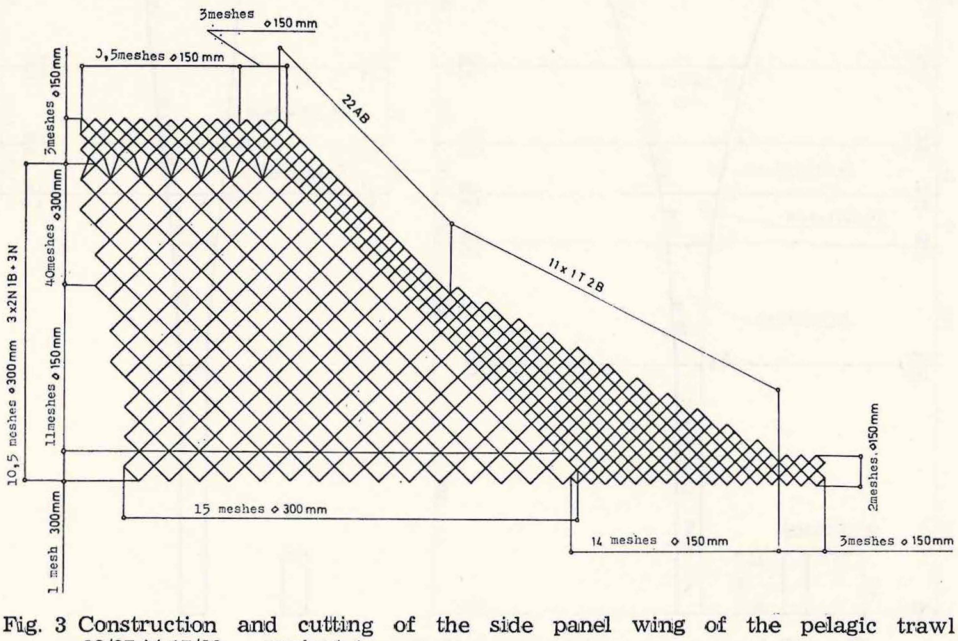


Fig. 3 Construction and cutting of the side panel wing of the pelagic trawl 32/37 × 17/22 — variant 1.

selvage of the wedge lengthening, has a slant cutting, and the wing wedges have a combined cutting. The coefficient of hanging on the boundary ropes was 1.00 and on the bosom 0.50. The boundary ropes were made of the steel rope wrapped in the polyamid twine.

The variant 2 model, shown in Fig. 4, differs from the variant 1 model by the construction of the top and lower wings. The wings on the side panel of that model from the point of view of construction are the same as in the variant 1 model. In this variant the wedges of the top and lower wings have been removed making the wings longer for 6 meshes at the expense of the

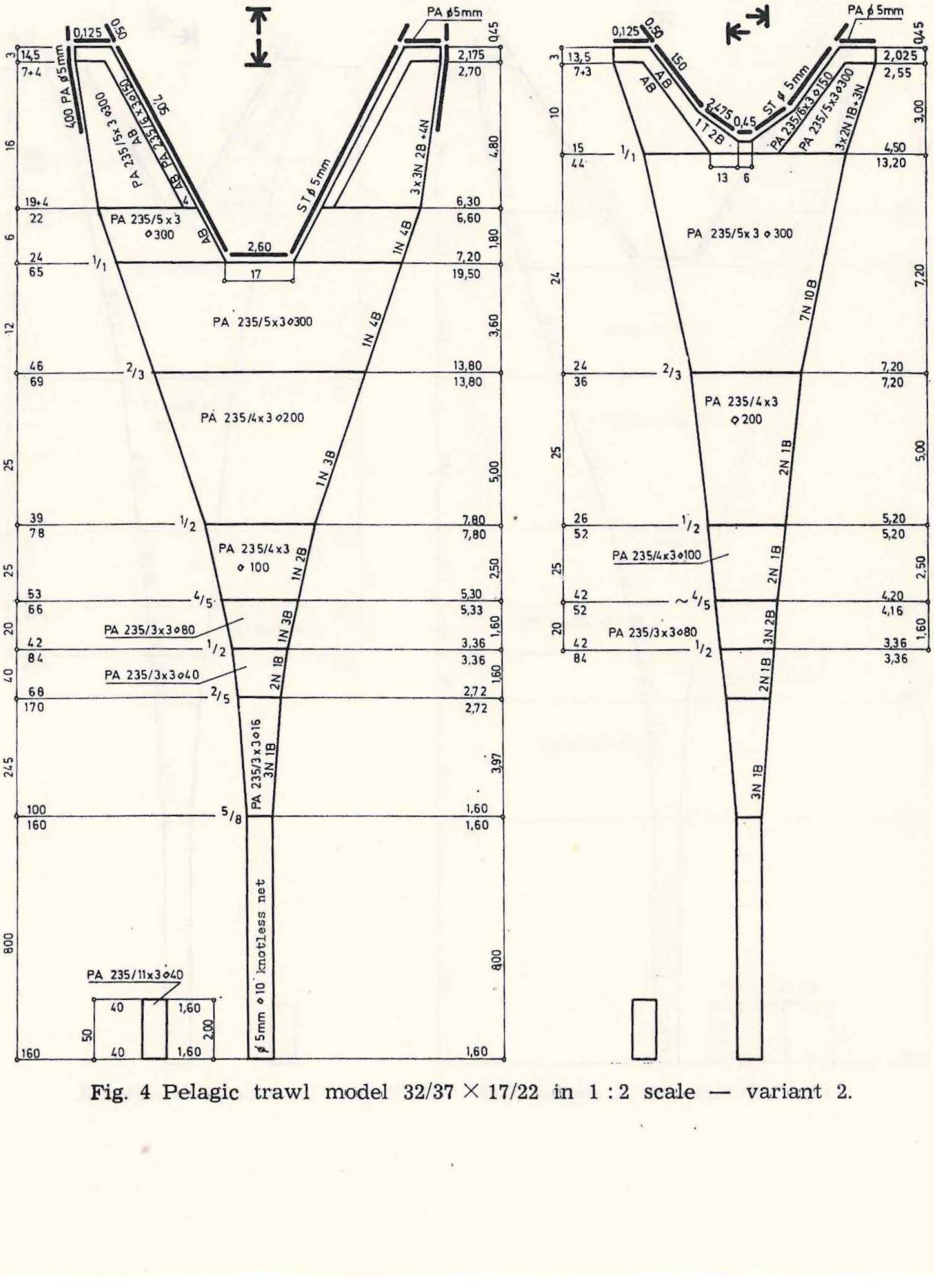


Fig. 4 Pelagic trawl model 32/37 × 17/22 in 1 : 2 scale — variant 2.

first segment of the belly. The top and lower wings of that model have a slant cutting all along the outer selvage, while the coefficient of hanging on the boundary ropes of these wings was 0.98 and on the bosom 0.50. The boundary ropes were also wrapped in polyamid twine.

In the variant 3 model, shown in Fig. 5, in relation to the model 2, the wedges and their lengthenings of the side panel wings were removed and in this way they were lengthened by 6 meshes at the expense of the first segment of the belly. The wings of the side panels of that model had a slant cutting along the outer selvage, while the coefficient of the hanging on the

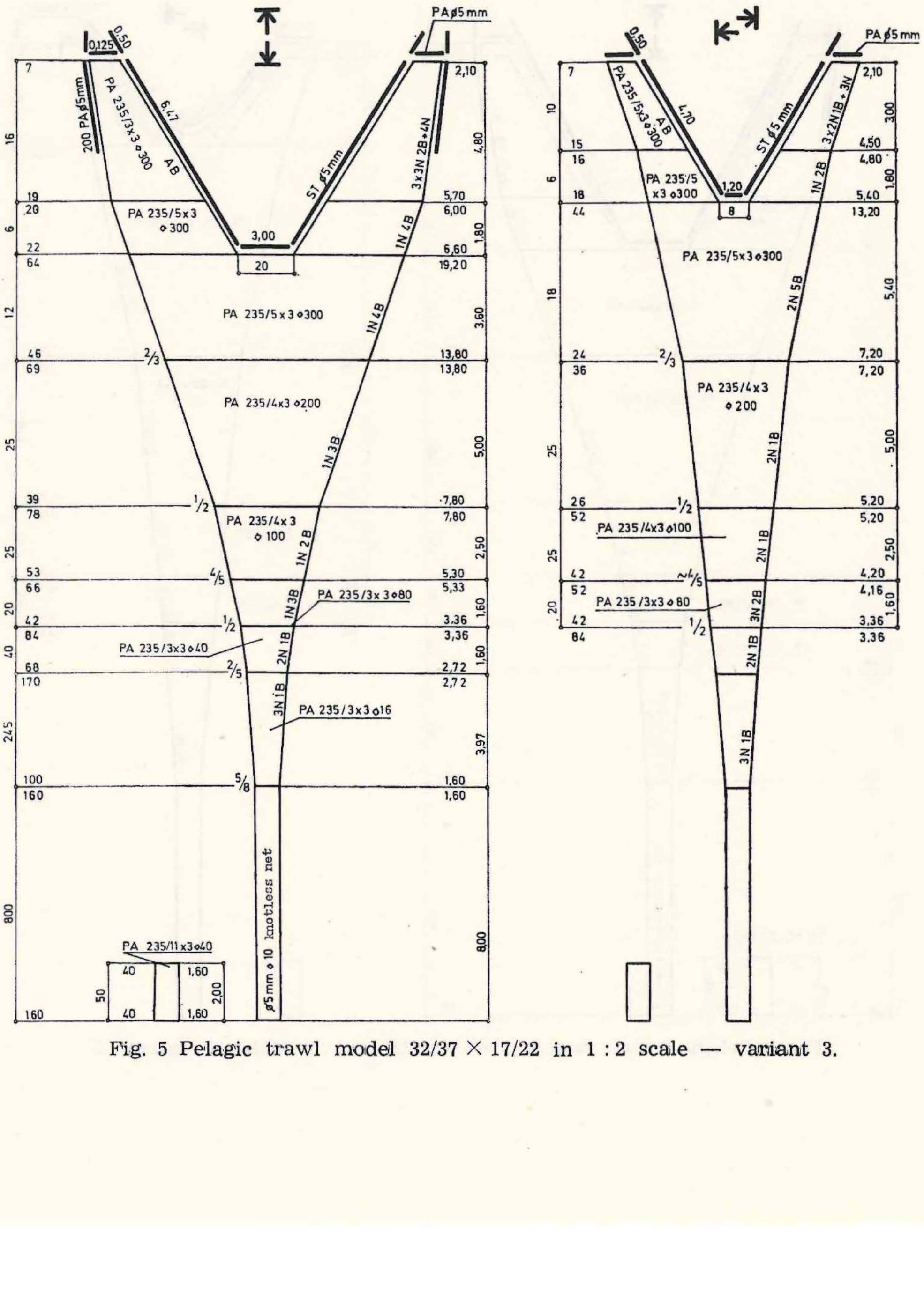


Fig. 5 Pelagic trawl model 32/37 × 17/22 in 1 : 2 scale — variant 3.

boundary ropes of these wings was 0.98 and on the breast 0.50. The boundary ropes were also wrapped in polyamid twine.

The variant 4 model, shown in Fig. 6, is the construction of the pelagic trawl with ropes. Compared with the original construction of the pelagic trawls (model variant 1), in this variant the depth of the first segment of the belly was shortened by 12 meshes and in this way this part of the belly was completed by a new segment with small wings to the tops of which a rope's end was fastened. The other ends of the rope were fastened to the ropes of the head rope, foot rope, and the side panels of the net. The construction of the small wings of the upper, lower and side panels of the variant 4 model is shown in Figs 7 and 8.

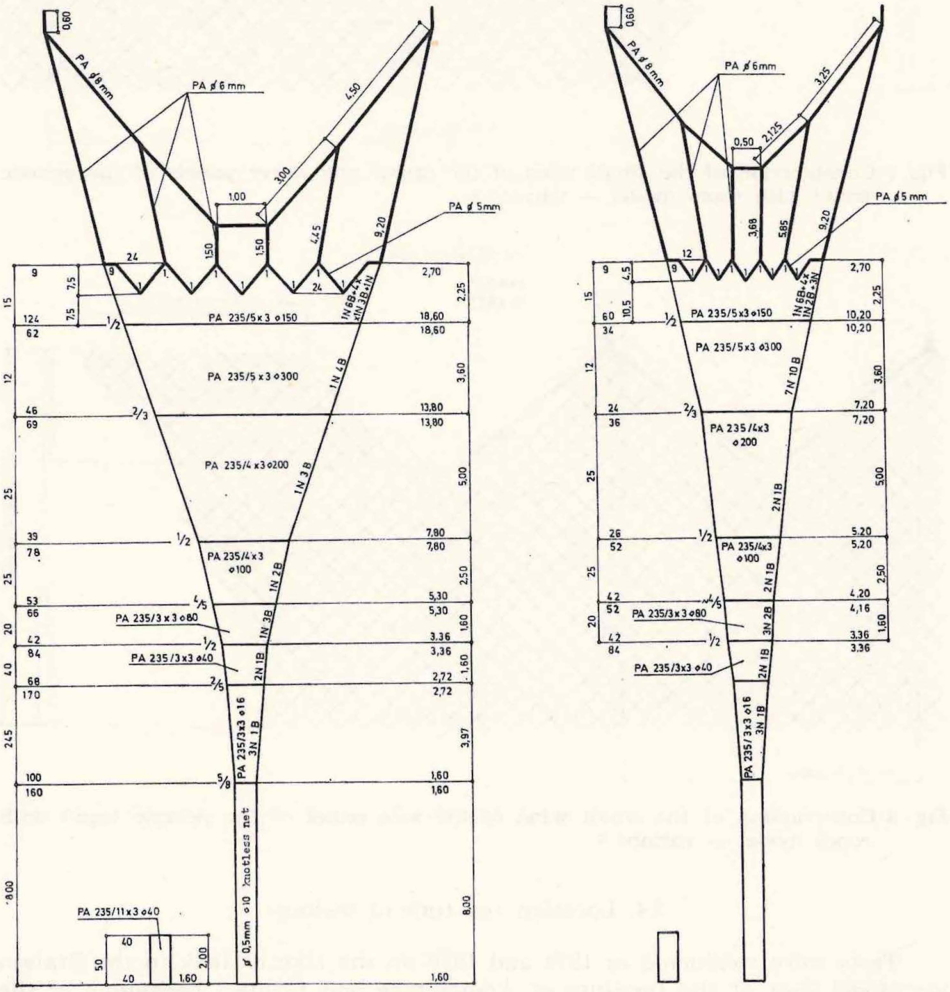


Fig. 6 Pelagic trawl model 32/37 × 17/22 in 1 : 2 scale — variant 4.

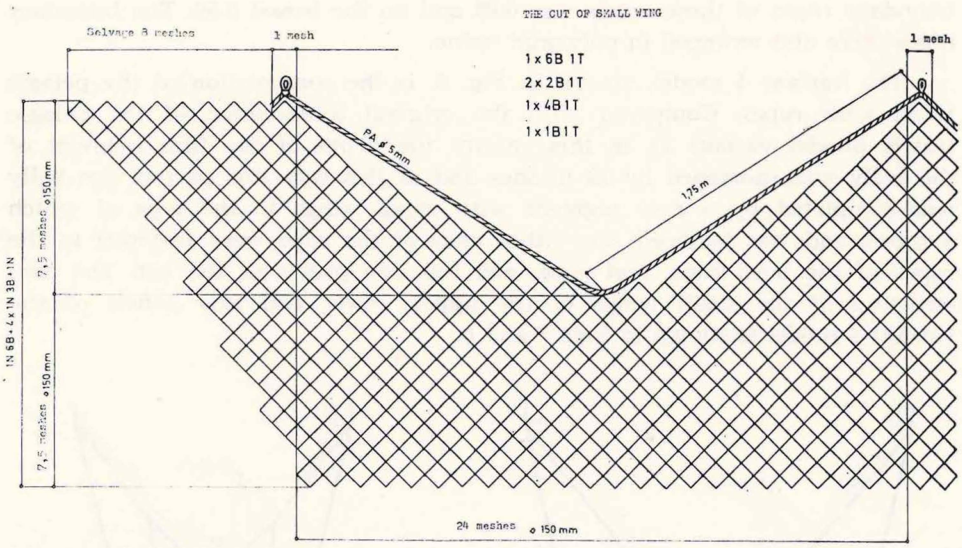


Fig. 7 Construction of the small wing of the upper and lower panels of the pelagic trawl with ropes model — variant 4.

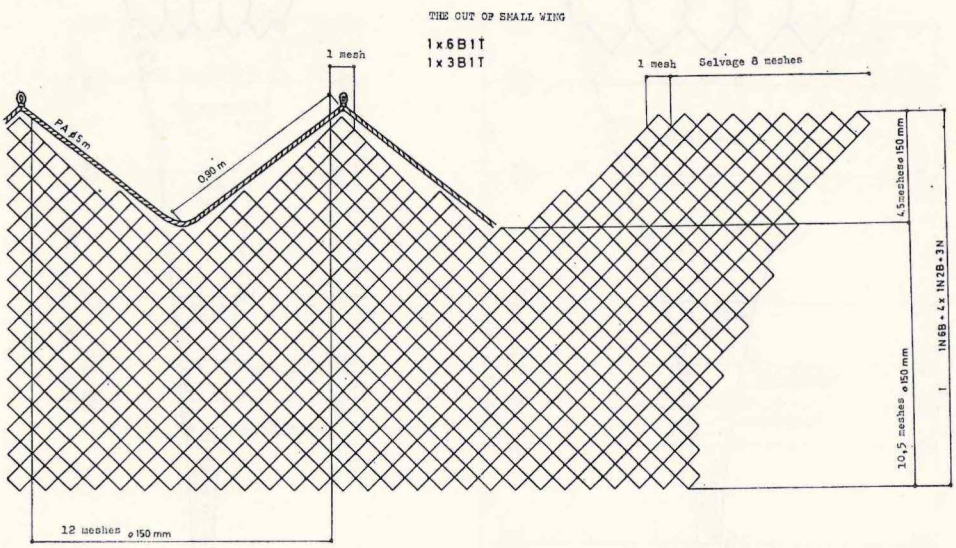


Fig. 8 Construction of the small wing of the side panel of the pelagic trawl with ropes model — variant 4.

2.4. Location and time of testing

Tests were conducted in 1974 and 1975 on the lake of Insk in the Station for Model Test of the Institute of Aquiculture and Fishing Technique of the Faculty of Sea Fishery and Nutrition Technology of the Agricultural Academy in Szczecin, Poland. The tested models were trawled by means of a measuring bridge of the catamaran type. In 1976 tests were conducted also in the Adriatic by the research ship »Predvodnik« of the Institute od Oceanography and Fisheries, Split.

2.5. Measuring values and measuring instruments

During the tests the following values were measured:

a) trawling speed (v),
b) warps tension (T),
c) angles of inclination of the warps (α),
d) warps spacing (r),
e) head line (g_n) and foot line (g_p) hauling depth,
f) length of released warps (l_t),
g) coefficient of the transversal (horizontal) opening of the netting mesh (u_x),
h) photographic documentation of the trawl body shaping under water, and underwater observations.

Ad a) The range of the measuring speeds of model trawling was 0.55 — 1.70 m/sec., which, according to the formula No. 15 following from Froude's criterion, corresponds to the approximate speed of trawling the actual gear 1.5 — 4.7 knots.

The trawling speed (v) was determined by the speedometers with electric indicator of speed. The speedometer in Photo 1 was used on the catamaran and in Photo 2 on the vessel.

Ad b) The tension of the warps was determined in kG with various dynamometers:

— electric (Photo 3), for measuring the tension of the warps on the catamaran at trawling the pelagic trawl models by one trawling boat (with otter-boards),

— load indication bridles (Photo 4), for measuring the resistance of the body of the pelagic trawl model which was spread on the poles of the measuring bridge of the catamaran,

— spring, for measuring the resistance of the body of the pelagic trawl model spread on the poles of the measuring bridge of the catamaran,

— hydrolic, for measuring the resistance of the fishing system of the models tested on the vessel (Photo 5).

Ad c) Angles of inclination of the right (α_P) and left (α_L warp were determined in degrees and measured with a spirit-level protractor.

Ad d) Warps spacing (r) was determined by measuring their spacing in cm at one metre's distance from the blocks hanging from the gallows (davit) of the trawler. The total spacing of the released warps is obtained by multiplying the length of the released warps with its spacing.

Ad e) The hauling depth of the head line (g_n) and the lead (foot) line (g_p) was measured on the bosom of the net. This parameter was determined by depthographs one of which was fastened to the bosom of the head line and the other on the lead (foot) line. Photo 6 shows the depthograph fastened on the head line of the model.

Ad f) Length of the released warps (l_t) was determined by marking the warps.

Ad g) The coefficient of the transversal opening of the netting (u_x) was determined analogously to the coefficient of the hanging netting. It represents the ratio of the length of the horizontal diagonal of the mesh (x) and the double length of the side of the mesh (2a — length of the stretched mesh) and it is calculated witk these formulae:

$$\text{horizontal } (u_x) = \frac{x}{2a} = \sin\frac{\varphi}{2} \tag{18}$$

$$\text{vertical } (u_y) = \frac{y}{2a} = \cos\frac{\varphi}{2} \tag{19}$$

where:

φ = the angle between the two sides of the mesh.

As $u_y = \sqrt{1 - u^2_x}$ and $u_x = \sqrt{1 - u^2_y}$ (this follows from the geometrical dependence of the shape of the square mesh of the netting), knowing one coefficient the other can be calculated.

At testing the coefficient of the transversal slit of the mesh (u_x) was determined in individual elements of the pelagic trawl model.

2.5.1. Characteristics of the catamaran and the vessel

The pelagic trawl models were trawled by means of the measuring bridge constructed as a catamaran and the research ship. The catamaran, shown in Photo 7, is 11.68 m long, 8.32 m wide, 3.70 m deep, 2 × 4.25 tons displacement, the main engine 2 × 105 HP and 5 m/sec speed. The space between the hulls is covered by mounted plates that make the deck of the catamaran. On the catamaran are two stern blocks through which the warps pass, and in the central part are two electric winches with drums for winding the warps. In the central part of the catamaran there is also the erection with rooms for the steering station (steerhouse) and with measuring instruments. The forebody of the catamaran has facilities for trawling the body of the trawl spread on special poles, which can be shifted both into vertical and horizontal positions. The scheme of the catamaran and the location of the trawl on it are shown in Fig. 9.

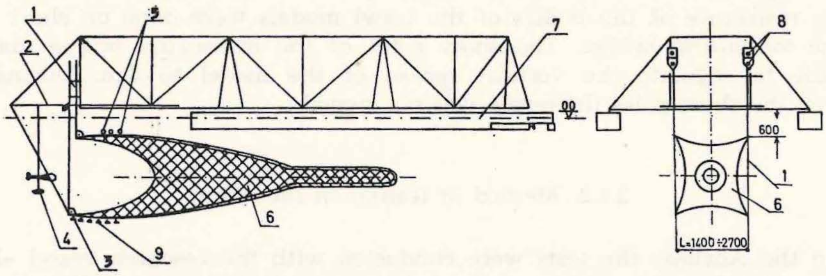


Fig. 9 Scheme of the catamaran with the spread body of the pelagic trawl model.

1. Vertical pole
2. Horizontal pole
3. Tackle
4. Speedometer
5. Floats on the head line
6. Pelagic trawl model
7. Measuring bridge
8. Dynamometers
9. Lead line burden

The vessel used in these tests was 18.90 m long, 4.85 m wide, the main engine had 225 HP. It was equipped with a seine winch with two drums on which the warps were wound. On the stern of the vessel there was a cylinder (roller) used for submerging and hauling the net. The distribution of the fishing equipment on the vessel is such that the vessel is adapted also for trawling.

2.6. Method of testing

2.6.1. *Method of testing on the measuring bridge*

The measuring bridge on the catamaran makes it possible to trawl the model in two ways:

a) trawling the trawl system of the models (trawl, otter-boards, bridles, warps) in the same way as trawling is done on industrial fishing vessels. The models ere trawled with two arps and their shooting and hauling as done by two electric winches.

b) trawling the body of the trawl model spread on the bow poles of the measuring bridge of the catamaran, shown schematically in Fig. 9. During trawling the model lies below the measuring bridge which makes it possible to observe it from the deck after the deck plates have been removed. The poles on which the ends of the wings of the tested model are spread can be shifted into the horizontal and vertical positions. In this way it is possible to regulate the horizontal spread of the model within the range of 0—7.6 m, and the vertical one of 0—6.5 m.

The resistance of the body of the trawl model spread on the poles is measured by four dynamometers, as shown in Photo 4, while the resistance of the model that is trawled by the warps is measured by two dynamometers fastened to them.

The bodies of the pelagic trawl models tested on the poles of the measuring bridge or with warps were rigged in the same way. Some measurings of the resistance of the bodies of the trawl models were done on short poles of the measuring bridge. The short poles of the measuring bridge make it possible to regulate the vertical spread of the model to 3 m. During the tests on the short poles the model was not rigged.

2.6.2. *Method of testing on the vessel*

In the Adriatic the tests were conducted with the research vessel »Predvodnik«. The models were trawled with normally rigged trawling system. The tests on the vessel involved the measuring of the basic techno-contructional and exploitational parameters of each variant of the model. The tests were conducted on calm sea so that on the fixed course of the ship, during trawling, the length of the released warps was measured, and after each such change the individual parameters were measured at the trawling speeds fixed inn advance. The same measurings were repeated also on the return course of the ship.

The rigging of the body of the model and whole trawling system tested on the ship, was the same as at trawling the model on the measuring bridge of the catamaran by means of the warps.

2.6.3. *Method of conducting underwater observations and photographing*

The aim of the underwater observations and taking of photographs was to evaluate the regularity of the construction of the bodies of the tested pelagic trawl models, the shaping of the individual elements and to determine the degree of the mesh slit in the analysed parts of the nnet.

The underwater observations and photographic documentation were conducted by the divers of the Institute of the Fishing Techniüue of the Faculty of Sea Fishery and Technology of Nutrition, Szczecin, who are also experts in the construction of the fishing gear.

The following equipment was used for underwater observations and photographing:

a) diving equipment consisting of bottles and SCUBA and personal outfit;

b) photographic accessories consisting of the underwater camera with a wide-angle objective, and electronic underwater flashlight;

c) equipment for towing the diver consisting of an aquaplane with the rope for towing and signalling, light system for signalling and an electric winch which was on the stern of the catamaran. Fig. 10 shows the places on the tested model of which photos were taken.

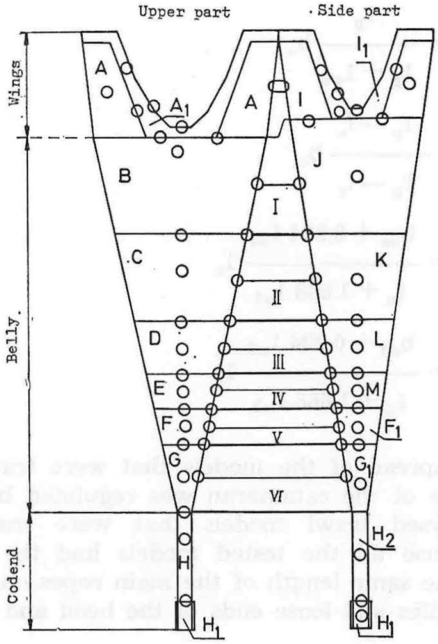


Fig. 10 Places on the model of which photos were taken

2.7. Calculated magnitudes

In addition to the parameters obtained by indirect measuring the following magnitudes were also calculated:

a) The vertical spread of the mouth of the belly of the trawl (h), which was determined by trawling the model on the warps from the difference between the hauling depth of the top and lower bosom, and by trawling the model stretched on the poles of the measuring bridge of the catamaran, by means of the spread and the hauling depth of the poles.

b) The indicators of the horizontal spread of the trawl which were measured:

— between the points that connect the head line and the main rope on the side panel of the trawl (b_o),

— on the ends of the side selvages (b_p),

— on the mouth of the belly (b),

— on the head line (b_n) and lead line (bd).

The indicators of the horizontal span of the trawl model were determined on the basis of similitude of triangles from the following formulae (K r e p a, 1974):

$$b_o = \frac{1_p + 1_{wn}}{1_p + 1_{wn} + 1_{w1}} b_r \tag{20}$$

$$b_p = \frac{1_p}{1_p + 1_{wn}} b_o \qquad (21)$$

$$b = \frac{1_p - l_s}{1_p - l_s} b_o \qquad (22)$$

$$b_n = \frac{b_{on} + 0.224\ 1_{w1}}{1_n + 1.668\ 1_{w1}} 1_n \qquad (23)$$

$$b_d = \frac{b_{od} + 0.224\ 1_{w2}}{1_d + 1.668\ 1_{w2}} 1_d \qquad (24)$$

The horizontal spread of the models that were trawled on the poles of the measuring bridge of the catamaran was regulated by the distance of the poles. In the analysed trawl models that were trawled on the warps $b_{on} = b_{od} = b_o$, because all the tested models had the same length of the tested models had the same length of the main ropes on the upper and lower parts of the net, bridles and loose ends of the head and lead lines and of the legs.

c) The distance between the otter-boards (b_r) was calculated with this formula:

$$b_r = \frac{1_t r}{100} + p \qquad (25)$$

d) The geometrical function of the trawling system (G_z) is the indicator of the surface of the mouth of the belly of the trawl (S_w), which, for the models trawled by warps (the mouth of the belly is oval in form similar to an ellipse), is determined by the formula:

$$S_w = \frac{\Pi}{4} b_r h\ (m^2) \qquad (26)$$

For the models that are trawled on the poles of the measuring bridge of the catamaran (the mouth of the belly is similar to a rectangle), S_w is determined by the formula:

$$S_w = hb_o\ (m^2) \qquad (27)$$

The geometrical function of the trawling system (G_z) is determined by the formula:

$$G_z = \frac{\Pi}{4} \frac{k_1 1_w + k_2 1_{p1}}{1_w + 1p_1} \frac{1_p - b_p}{1_p} b_r h\ (m^2) \qquad (28)$$

e) The geometrical motional function of the trawling system of the trawl (G_{zv}), which is the indicator of the size of penetration and reflects the quantity of the collected and filtered water in a time unit, is determined by the formula:

$$G_{zv} = G_z \, v \ (m^3/h) \tag{29}$$

f) The coefficients of the spread of the head line (λ_n) and lead line (λ_d) are determined by the relationships of the lengths of the main ropes, and are calculated by the formula:

$$\lambda_n = \frac{b_n}{l_n} \tag{30}$$

$$\lambda_d = \frac{b_d}{l_d} \tag{31}$$

The coefficient of the spread of the trawling system (λ_z) is equal to the coefficient of the spread of the side panel selvages of the trawl (λ_p) and is determined by the formula (Krepa, 1974):

$$\lambda_z = \lambda_p = \frac{b_p}{2l_p} \tag{32}$$

The coefficients of the transversal spread of the mesh (u), which determines the shape of the netting and the degree of its exploitation in individual elements of the fishing gear, are calculated by the formula (Krepa and Swiniarski, 1975):

$$u = \frac{\Pi (b + h)}{2S_o}$$

$$S_o = 4 \, S_2 \tag{33}$$

g) The tow-rope resistance (R_z) is determined by the formula (Krepa, 1974):

$$R_z \cong T_P \cos\alpha_P \cos\gamma + T_L \cos\alpha_L \cos\gamma \ (kG) \tag{34}$$

h) The tow-rope power (N_h) is determined by the formula (Krepa, 1974):

$$N_h = \frac{R_z \, v}{75} \ (HP) \tag{35}$$

At calculating the tow-rope power, the trawling speed is expressed in knots (miles per hour).

The symbols in the formulae are:

l_{wn} = length of the loose ends and the bridles of the head line (m),

l_p = length of the trawl from the top of the wing part to the end of the belly, namely, the beginning of the cod end (m),

l_{w1} = length of the upper leg (m),

l_{w2} = length of the lower leg (m),

l_s = length of the wings along the selvage (m),

l_w = length of the leg with loose ends (m),

l_{p1} = length of the upper wings (m),

l_n = length of the head line (m),

l_d = length of the lead line (m),

b_{on} = horizontal spread of the upper (head line) part of the net (m),

b_{od} = horizontal spread of the lower (lead line) part of the net (m),

p = distance between the winches hanging from the trawler gallows on the vessels with a stern system of trawling (m),

k_1 = constant relative to the capacity of leg contraction, the value of which for the pelagic trawls is 0.1 (Krepa, 1974),

k_2 = constant relative to the capacity of wing contraction, the value of which for he pelagic rawls is 0.5 (Krepa, 1974),

γ = angle of warp spacing which at the existing spreads between the otter-boards and to 400 m of released warps are from 2—7° ($\cos\gamma \cong 1$),

S_2 = width of the belly on the mouth of the trawl at the stretched netting (m).

3. REZULTS AND ANALYSIS OF THE TESTS

3.1. Analysis of the constructionnal characteristics of the pelagic trawls

3.1.1. *General constructional requirements of the pelagic trawls*

The basic prereüuisite for realizing efficient results of the catch is to dispose with such fishing gears that are adapted to the technical parameters of the fishing vessel, fishing regions, and the specific life and behaviour of the caught fish species.

During the works on the designing and rigging the constructional characteristics of the tested trawls were adapted to pilchard catches in the fishing grounds of the Northern Adriatic, in which, to our present knnowledge, real possibilities and conditions exist for applying this fishing gear. The pilchard shoals in these fishing grounds are in relatively small concentrations with great speed of movement and strong reaction to outside impulses. During day and night these shoals keep horizontal and vertical migrations. At night they generally gather in larger concentrations in the upper and surface layers of the sea, while by day they are dispersed in the bottom layers.

At designing the analysed fishing gear these characteristics of the fish species were taken into account.

The basic sizes that characterize the construction of the pelagic trawls are, first of all, the elements of the contracting parts that affect the shape and size of the whole body of the gear, the mouth of the belly in particular. The shaping of these parameters influences greatly the catchability of the fishing gear.[4])

Tests conducted by a number of authors (Fridman, 1969, Swiniarski, 1974, Swiniarski, Krepa, 1975, Ziebo, 1976) show that the catchability of the trawls depends, in addition to other things, on the surface of the mouth, trawling speed, and distance from which fish react to the fishing gear. The fishing practice, however, shows that the catchability of trawls depends, above all, on the penetration the net ensures during fishing. The indicator which marks the extent of penetration on the bottom surface and the volume of the water column ensured by the corresponding trawling system depends on:

- the size of the mouth of the trawl,
- distance between the otter-boards,
- length of the leg or the bridles,
- length of the wings and the square of the trawl,
- inclination of the cone of the netting of the trawl in relation to the direction of its movement,
- trawling speed.

The ecologic zones of fishing, the character of the shoal formed by individual species of the caught fish during day and night, the linear features of the gear and its shaping during trawling, especially the shape of the mouth of the trawl, have a significant influence on its catchability.

3.1.2. *Analysis of the horizontal and vertical spread and shape of the mouth of the trawl*

The size of the vertical and horizontal spread of the trawl depends, first of all, on the dimension of its belly, size of the elements of rigging, length of the released warps, and the trawling speed. The vertical and horizontal spreads of the tested pelagic trawl models at various lengths of the released warps and the changing speed of trawling are shown in Tables 1, 2 and 3. From these tables it follows that the vertical and horizontal spreads depend mainly on the construction of the contracting elements (mouth elements) of the analysed trawls. In all the analysed cases, by increasing the trawling speed and length of the released warps, the vertical spread of the

[4]) The catchability of the fishing gear determines its capability of catching and efficiency, namely the property of the gear or the degree of its adaptability to catching fish and other water organisms. Catchability is defined as the relationship between the quantity of the fish caught with a certain fishing gear and the quantity of the fish which appears within the range of operation of this fishing gear and can be caught.

Table 1. Measurement results, calculated linear magnitudes, and tow-rope resistance of the trawling system of the pelagic trawl model — variant 2

Mesure No.	Length of re- leased warps	Trawling speed		Warp tension left	Warp tension right	Warp tension total	Warp angles incidence left	Warp angles incidence right	Trawl bosom hauling depth head line	Trawl bosom hauling depth lead line	Warp spacing	Horizontal spread					Vertical spread	Tow- rope resi- stance
	Measured magnitudes										Calculated magnitudes							
	l_t m	v m/s	knots	T_L kG	T_P kG	R kG	αL degrees	αP m	g_n m	g_p m	r cm	b_r m	b_o m	b_p m	$b_n - b_d$ m	b m	h m	R_z kG
1	30	0.68	1.32	65	68	133	28	28	26	36	7	6,6	3.49	3.42	3.37	2.89	10.0	117.43
2	30	0.96	1.86	78	80	158	24	24	17	25.5	12	8.1	4.29	4.2	4.10	3.56	8.5	144.34
3	30	1.10	2.13	101	105	206	18	18	14	21	16	9.3	4.92	4.82	4.67	4.08	7.0	195.91
4	30	1.22	2.37	114	118	232	15	15	10	16	19	10.2	5.40	5.29	5.11	4.48	6.0	224.09
5	30	1.36	2.64	130	138	268	10	10	—	10	21	10.8	5.72	5.60	5.4	4.74	—	263.92
6	40	0.70	1.36	72	75	147	29	29	26	35.5	8	7.7	4.08	3.99	3.91	3.38	9.5	128.56
7	40	0.94	1.82	83	86	169	26	26	20	28	15	10.5	5.56	5.44	5.25	4.61	8,0	151.89
8	40	1.10	2.13	107	110	217	20	20	15	22	18	11.7	6.20	6.07	5.84	5.14	7.0	203.91
9	40	1.22	2.37	120	124	244	17	16	10	16	21	12.9	6.83	6.69	6.41	5.66	6.0	233.95
10	40	1.32	2.56	140	144	284	12	12	—	10	25	14.5	7.68	7.52	7.18	6.37	—	277.79
11	50	0.80	1.55	65	69	134	27	28	27	35	12	10.5	5.56	5.44	5.25	4.61	8.0	118.83
12	50	0.94	1.82	75	80	155	25	25	21	28	15	12.0	6.36	6.23	5.98	5.27	7.0	140.47
13	50	1.15	2.23	107	108	215	19	19	17	23	19	14.0	7.42	7.27	6.94	6.15	6.0	204.23
14	50	1.40	2.72	153	156	309	13	13	12	17.5	21	15.0	7.95	7.79	7.43	6.59	5.5	301.08
15	60	0.94	1.82	85	89	174	28	28	27	35	12	11.7	6.20	6.07	5.84	5.14	8.0	153.63
16	60	1.13	2.19	110	113	223	22	22	20	27	14	12.9	6.83	6.69	6.41	5.66	7.0	206.76
17	60	1.38	2.68	153	156	309	17	17	15	21	18	15.3	8.10	7.93	7.56	6.72	6.0	295.49
18	60	1.51	2.93	165	171	336	15	15	11	17	24	18.9	10.01	9.00	9.30	8.3	6.0	324.55
19	60	1.68	3.26	201	204	405	12	12	—	12	28	21.3	11.28	11.05	10.45	9.36	—	396.14
20	80	0.96	1.86	96	98	194	29	29	32	39.5	14	15.7	8.32	8.15	7.76	6.90	7.5	169.67
21	80	1.14	2.21	116	120	236	23	23	28	35	17	18.1	9.59	9.39	8.92	7.95	7.0	217.23
22	80	1.22	2.37	139	140	279	19	19	23	30	20	20.5	10.86	10.64	10.07	9.01	7.0	263.79

23	80	1.46	2.83	168	170	338	16	16	16	22	22	22.1	11.71	11.47	10.85	9.71	6.0	324.90
24	80	1.69	3.28	208	209	417	14	14	11	16	23	22.9	12.13	11.88	11.23	10.06	5.0	404.61
25	100	1.12	2.17	120	124	244	24	24	34	40.5	12	16.5	8.74	8.56	8.14	7.25	6.5	222.90
26	100	1.25	2.42	142	145	287	20	20	28	34	14	18.5	9.8	9.6	9.11	8.13	6.0	269.69
27	100	1.35	2.62	160	166	326	18	18	22	27	15	19.5	10.33	10.12	9.59	8.57	5.0	310.04
28	100	1.50	2.91	178	183	361	16	16	18	23	17	21.5	11.39	11.16	10.55	9.45	5.0	347.01
29	100	1.70	3.30	213	216	429	14	14	12	16	19	23.5	12.45	12.20	11.52	10.33	4.0	416.25
Mean values			2.33									14.92	7.90	7.74	7.38	6.55	6.71	242.38

Constructional data: $p = 0$; $l_{w1} = 22.5$ m; $l_{w2} = 22{,}5$ m; $l_n = l_d = 16{,}7$ m; $l_p = 25{,}32$ m; $l_s = 7{,}05$ m; $l_b = 3{,}45$ m; $l_{wn} = 0{,}5$ m; $l_w = l_{w1} + l_{wn} = 23$ m; $l_{p1} = 7{,}05$ m; $S_2 = 17{,}10$ m;

Table 2. Measurement results, calculated linear magnitudes, and tow-rope resistance of the trawling system of the pelagic trawl model — variant 3

Mesure No.	Length of released warps	Trawling speed		Warp tension			Warp angles incidence		Trawl bosom hauling depth		Warp spacing		Horizontal spread				Vertical spread	Tow-rope resistance
				left	right	total	left	right	head line	lead line								
	l_t m	v m/s	knots	T_L kG	T_P kG	R kG	αL degrees	αP m	g_n m	g_p m	r cm	b_r m	b_0 m	b_p m	$b_n - b_d$ m	b m	h m	R_z kG
1	30	0.70	1.36	59	62	121	26	25	24	34.5	8	6.9	3.53	3.50	3.44	3.25	10.5	109.21
2	30	0.96	1.86	71	74	145	23	23	17	26	12	8.1	4.21	4.12	4.01	3.83	9.0	133.47
3	30	1.13	2.19	96	99	195	16	16	14	21.5	15	9.0	4.68	4.58	3.43	4.25	7.5	187.44
4	30	1.22	2.37	109	112	221	13	14	11	17.5	18	9.9	5.14	5.03	4.85	4.67	6.5	214.87
5	30	1.35	2.62	127	130	257	9	9	—	12	20	10.5	5.46	5.35	5.14	4.96	—	253.83
6	50	0.94	1.82	65	68	133	22	22	22	31	13	11.0	5.72	5.60	5.38	5.20	9.0	123.31
7	50	1.11	2.15	93	97	190	18	19	15	22.5	15	12.0	6.24	6.11	5.85	5.67	7.5	180.16
8	50	1.28	2.48	114	118	232	14	14	12	18.5	20	14.5	7.54	7.38	7.02	6.86	6.5	225.10
9	50	1.32	2.56	121	125	246	13	14	11	17.5	21	15.0	7.80	7.64	7.26	7.09	6.5	239.18
10	50	1.42	2.76	138	142	280	11	11	8	14	22	15.5	8.06	7.89	7.49	7.33	6.0	274.85
11	80	0.96	1.86	91	95	186	27	28	30	38	14	15.7	8.16	7.99	7.58	7.42	8.0	164.96
12	80	1.15	2.23	110	115	225	22	22	26	33	18	18.9	9.82	9.62	9.09	8.93	7.0	213.26
13	80	1.25	2.42	130	133	263	19	19	23	29,5	20	20.5	10.66	10.44	9.85	9.70	6.5	248.67
14	80	1.46	2.83	158	161	319	15	15	15	21	22	22.1	11.49	11.26	10.60	10.45	6.5	308.13
15	80	1.70	3.30	199	203	402	13	14	10	15.5	23	22.9	11.90	11.66	10.97	10.82	5.5	390.86
16	100	0.94	1.82	81	79	160	26	26	35	42	11	15.5	8.06	7.89	7.49	7.33	7.0	143.80
17	100	1.04	2.02	99	104	203	24	25	32	38.5	12	16.5	8.58	8.4	7.97	7.80	6.5	184.69
18	100	1.23	2.39	114	118	232	20	20	27	33	14	18.5	9.62	9.42	8.91	8.75	6.0	218.00
19	100	1.32	2.56	129	134	263	17	18	23	29	15	19.5	10.14	9.93	9.38	9.22	6.0	250.80
20	100	1.51	2.93	170	173	343	15	14	17	22	17	21.5	11.18	10.95	10.32	10.17	5.0	332.06
21	100	1.68	3.26	205	209	414	12	12	12	16.5	19	23.5	12.22	11.97	11.26	11.12	4.5	404,95
	Mean values		2.37									15.59	8.10	7.93	7.53	7.36	6.87	228.64

Constructional data: $p = 0$; $l_{w1} = 22,5$ m; $l_{w2} = 22.5$ m; $l_n = l_d = 15.94$ m; $l_p = 24.87$ m; $l_s = 6.6$ m; $l_b = 4.80$ m; $l_{wn} = 0.50$ m; $l_{pl} = 6.6$ m; $S_2 = 16.80$ m;

Table 3. Measurement results, calculated linear magnitudes, and tow-rope resistance of the trawling system of the pelagic trawl model with ropes — variant 4

	Measured magnitudes										Calculated magnitudes							
Mesure No.	Length of released warps	Trawling speed		Warp tension			Warp angles incidence		Trawl bosom hauling depth		Warp spacing	Horizontal spread					Vertical spread	Tow-rope resistance
				left	right	total	left	right	head line	lead line								
	l_t	v		T_L	T_P	R	αL	αP	g_n	g_p	r	b_r	b_o	b_p	$b_n - b_d$	b	h	R_z
	m	m/s	knots	kG	kG	kG	degrees		m	m	cm	m	m	m	m	m	m	kG
1	30	0.65	1.26	46	47	93	26	25	23	32	10	7.5	4.27	4.18	4.06	3.84	9.0	83.94
2	30	0.90	1.74	62	65	127	23	22	16	—	12	8.1	4.61	4.51	4.37	4.14	7.5	117.33
3	30	1.15	2.23	88	88	176	15	15	13	20	16	9.3	5.30	5.19	5.00	4.77	7.0	170.00
4	30	1.28	2.48	101	103	204	12	12	10	16	18	9.9	5.64	5.52	5.31	5.07	6.0	199.54
5	30	1.40	2.72	120	123	243	9	9	—	10	21	10.8	6.15	6.02	5.77	5.53	—	240.00
6	50	0.95	1.84	60	60	120	21	21	21	28	13	11.0	6.27	6.14	5.88	5.64	8.0	112.02
7	50	1.15	2.23	90	88	178	17	17	17	24	17	13.0	7.41	7.26	6.91	6.66	7.0	170.22
8	50	1.30	2.52	110	110	220	13	13	15	21	19	14.0	7.98	7.82	7.42	7.18	6.0	214.36
9	50	1.38	2.68	120	125	245	10	11	11	17	21	15.0	8.55	8.37	7.94	7.69	6.0	240.88
10	50	1.45	2.81	130	135	265	8	8	11	12	23	16.0	9.12	8.93	8.46	8.20	—	262.42
11	80	1.00	1.94	81	80	161	26	26	30	37	12	14.1	8.03	7.86	7.47	7.22	7.0	144.70
12	80	1.15	2.23	100	100	200	21	21	23	29	15	16.5	9.41	9.21	8.71	8.46	6.0	186.71
13	80	1.28	2.48	119	121	240	17	17	20	25.5	17	18.1	10.31	10.10	9.53	9.27	5.5	229.51
14	80	1.50	2.91	140	143	283	14	14	16	20	20	20.5	11.68	11.44	10.78	10.51	4.0	274.59
15	80	1.65	3.20	170	165	335	11	11	11	15	22	22.1	12.59	12.33	11.60	11.33	4.0	328.84
16	100	1.00	1.94	85	85	170	24	25	35	41	11	15.5	8.83	8.65	8.19	7.94	6.0	154.68
17	100	1.10	2.13	100	96	196	20	20	30	36	13	17.5	9.97	9.77	9.23	8.97	6.0	184.17
18	100	1.32	2.56	120	121	241	16	16	24	29	15	19.5	11.11	10.88	10.26	9.99	5.0	231.66
19	100	1.41	2.73	140	140	281	15	15	20	25	16	20.5	11.68	11.44	10.78	10.51	5.0	271.42
20	100	1.51	2.93	162	163	325	13	12	15	19	18	22.5	12.82	12.56	11.81	11.53	4.0	317.28
Mean values			2.37									15.07	8.58	8.40	7.97	7.71	6.05	206.71

Constructional data: $p = 0$; $l_{w1} = 22.5$ m; $l_{w2} = 22.5$ m; $l_n = l_d = 16.0$ m; $l_p = 29.72$ m; $l_s = 7.7$ m; $l_b = 5.52$ m; $l_{wn} = 0.60$ m; $l_w = l_{w1} + l_{wn} = 23.10$ m; $l_{p1} = 7.7$ m; $S_2 = 18.90$ m;

net is reduced and the horizontal one enlarged. This is the general reaction of all the trawling fishing gears so that in this sense their work should be regarded as regular.

By analysing the mean values, it can be concluded that the largest mean vertical spread of the mouth of the belly (7.71 m) was achieved with the model variant 4 and, simultaneously, it got the smallest mean vertical spread (6.05 m). The smallest mean horizontal spread (6.55 m) was achieved with the model variant 2, and the largest vertical mean spread (6.87 m) with the model variant 3. A smaller vertical and, at the same time, a larger horizontal spread of the variants 3 and 4, the 4 especially so, was caused by a smaller lift force of the net elements in these models. Namely, in the models of the variant 3 the wedges of the wings and a part of the netting from the first segment of the belly were removed. In the model variant 4 the net elements of the first segment of the belly and wings, i.e. the net elements of the contracting part of the belly were replaced by ropes. Their actual surface was considerably smaller than the surface of the netting in the same part of the net in the models of other variants. Analogously, the lift force, which affects considerably the size of the vertical spread, was also considerably smaller in the model with ropes (variant 4). It caused a smaller vertical spread of the mouth of that trawl and, simultaneously, a larger horizontal spread. Such shaping of the mouth of the belly in the model variant 4 is suitable for catching dispersed and smaller day concentrations of pilchards gathering aabove the bottom.

The relationship between the vertical and horizontal spreads $\left(\frac{h}{b}\right)$ of the tested models was 1.02 for the variant 2, 0.93 for the variant 3, and 0.78 for the variant 4. These values for the pelagic trawls should be from 0.6 — 0.8 to 1.0 (Swiniarski, Krepa, 1975).

On the basis of the mean values of the vertical (h) and horizontal (b) spreads (Tables 1, 2 and 3) it follows that the mouth of the belly of the models 2 and 3 variants is oval and of the variant 4 elliptical with the longer horizontal diagonal. The model variant 4 ($h = 6.05$ m, $b = 7.71$ m) has the most suitable mean values of the horizontal and vertical spreads.

3.1.3. *Analysis of the shape of the pelagic trawls based on the constructional indicators*

For evaluating the exploitational characteristics of the pelagic trawls, besides the shape of the mouth of the trawl, the shaping of the net part of the whole gear (body of the trawl) and the trawling system is of greatest significance.

The analysis of the shaping of the body of the trawl and the trawling system is based on the constructional indicators:

— coefficient of the spread of the head line (λ_n) and the lead line (λ_d),

— coefficient of the spread of the trawling system (λ_z) or the side selvages (λ_p),
— coefficient of the transversal spread of the mesh of the netting on the mouth of the belly (u).

These are, of course, the variable indicators which depend mainly on the working regime of the trawling system.

Independently of the above analysis the shaping of the trawl body will be evaluated on the basis of the underwater photographic documentation in he part 3.1.5.

On the basis of the mean values of the horizontal and vertical spreads the variable indicators of the trawling system of the tested models, shown in Table 4, were determined. These values for individual variants of the tested models are:

— for the model variant 2:
$\lambda_n = \lambda_d = 0.441$
$\lambda_z = \lambda_p = 0.152$
$u = 0.332$

— for the model variant 3:
$\lambda_n = \lambda_d = 0.472$
$\lambda_z = \lambda_p = 0.159$
$u = 0.332$

— for the model variant 4:
$\lambda_n = \lambda_d = 0.498$
$\lambda_z = \lambda_p = 0.141$
$u = 0.285$

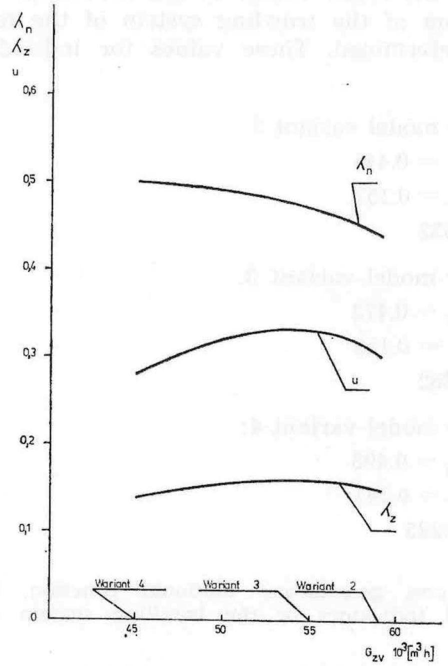
Table 4. Geometrical and geometrical motional function, tow-rope power and constructional indicators of the trawling system of the pelagic trawl models

Trawl model construction	Geometrical function[8])	Geometrical motional function[8]	Tow-rope power	Spread coefficient head/lead line	Trawling system spread coefficient	Mesh spread coefficient
Variant 2	13.47	58×10^3	7.52	0.441	0.152	0.304
Variant 3	12.58	55×10^3	7.22	0.472	0.159	0.332
Variant 4	10.27	45×10^3	6.53	0.498	0.141	0.285

[8]) The function G_z and G_{zv} were calculated by taking the value k_1 — 0.1 and k_2 — 0.5

The obtained values of these indicators are within the limits of the values obtained by other authors (S w i n i a r s k i, K r e p a, 1975). We can assume that the agreement of the values obtained by other authors with the values of the constructional indicators obtained in the present researches shows the correctness of the construtcional solutionst of the analysed pelagic tratwl models. It should be pointed out that these models are the corrected versions of the model variant 1. The constructional changes of these models were carried out mainly on the basis of direct underwater observations by eliminating the noticed constructional imperfactions.

The constructional indicators of the trawling system of the analysed pelagic trawl models, depending on the geometrical motional function are shown in Graph 1. It follows from this graph that by increasing the geometrical motional function the coefficient of the spread of the head line decreases, which reaches the greatest value at the smallest value of the geometrical motional function (variant 4).



Graph 1. Constructional indicators of the trawling system of the analysed pelagic trawl models.

The analysed pelagic trawls have approximate values of the coefficient of the spread of the trawling system, which follows from the fact that also the basic dimensions of the analysed trawls do not mutually differ very much. The differences shown on Graph 1, however, results from the constructional differences of individual models of the tested pelagic trawls.

The model variant 4 has the smallest value of the coefficient of the trawling system (λ_z) and also the smallest value of the geometrical motional function at the same time. The model variant 2 has the value λ_z smaller than the model variant 3, but somewhat greater than the model variant 4. Such a value of the spread coefficient of the trawling system of the model variant

4 in relation to the models variants 2 and 3 follows from the greater length of the body of the model (1_p) of the variant 4, which to a certain degree influences the magnitude of the mentioned coefficient.

Similarly to the spread coefficient of the trawling system behaves also the spread coefficient of the mesh of the netting on the mouth of the belly (u) in all the tested models depending on the value of the geometrical motional function Such values of this coefficient are conditioned by the width of the belly on the mouth of the net at stretched netting (S_2). The model variant 4 has the greatest value of the spresd coefficient of the mesh of the netting on the mouth of the belly.

Except for the spread coefficient of the netting mesh on the mouth of the belly, on the basis of the underwater photography analysis, the coefficients of the horizontal spread of the mesh (u_x)) are also determined in individual parts of the body of the net of the model variant 1. These values, shown in Tables 5 and 6, show that the meshes of each segment of the net have

Table 5. Coefficient of the horizontal spread of the mesh (u_x) in the upper panel of the belly of the pelagic trawl model — variant 1

Constructional element of the trawl model	Places on the trawl body of which photos were taken			
	Lower selvage of element	Central part of the element	Upper selvage of the element	Area of the side selvages of the element
1st belly segment (B)	0.49	0.75	0.50	—
2ng belly segment (C)	0.28	0.45	0.46	0.30
3rd belly segment (D)	0.30	0.26	0.31	0.28
4th belly segment (E)	0.25	0.26	0.28	0.24
5th belly segment (F)	0.22	0.24	0.25	0.20

Table 6. Coefficient of the horizontal spread of the mesh (u_x) in the side panel of the body of the pelagic trawl model — variant 1

Constructional element of the trawl model	Places on the trawl body of which photos were taken			
	Lower selvage of element	Central part of the element	Upper selvage of the element	Area of the side selvages of the element
Wing (I)	—	0.38	—	—
1st belly segment (J)	0.28	0.38	—	0.31
2nd belly segment (K)	0.25	0.25	0.26	0.22
3rd belly segment (L)	0.20	0.22	0.21	0.20
4th belly segment (M)	0.18	0.23	0.22	0.19
5th belly segment (F_1)	0.21	0.22	0.23	—

different coefficients of the horizontal spread. Also, on the same segment, but at different places, different values of the coefficient of the horizontal spread of the netting mesh are present.

Such a phenomenon can be, in one hand, explained by the shape of the net body itself which is created by trawling it in the water, which, in a certain sense, also corresponds to the constructional hypothesis of the analysed net, and, in the other hand, to its constructional imperfections and also to the way the netting is hanging on the boundary ropes, which, in a certain way, deforms the netting on individual parts of the trawl. These deformations are seen on the underwater photos 8, 9, and 10. Similar values of the mesh spread are given also by Korotkov and Kuzmin (1972), corroborated also by the tests by Kwidzinski, Nowakowski, Sendlak, Dudko, and Sadowska (1976).

By basing it on the analysis of the underwater photos, presented in 3.1.5., and on direct observations, it was stated that the deformations of the construction occurred on the mouth of the trawl, namely, on the bosom and wings, and on the places of the hanging netting. This influenced negatively the value of the coefficient of the horizontal opening of the mesh in those parts of the net. This is the reason why the coefficients of the mesh opening on the wings and on the beginning of the first segment of the belly have orientational values.

The deformations on the wings and the first segment of the belly gradually disappeared towards the cod end, which was confirmed by the direct underwater observations and photo documentation.

By comparing the values in the individual parts of the same segments of the belly, it has been noticed that the coefficients of the horizontal spread of the mesh in the upper part of the trawl have greater values in relation to the segments of the side panel. In addition, the horizontal opening of the mesh decreased in individual segments towards the cod end.

3.1.4. *Analysis of the geometrical and geometrical motional function*

The value of the geometrical (G_z) and geometrical-motional function (G_{zv}) are shown in Table 4. These values were calculated on the basis of the mean horizontal and vertical spreads, and on the speed of trawling the analysed variants of the pelagic trawl models. From the data shown in Table 4 it follows that the model variant 2 has the greatest value of the geometrical and geometrical-motional function and the variant 4 the smallest. The decline of the values of the geometrical and the geometrical-motional function in the models variants 3 and 4, in relation to the model variant 2, was caused by the decrease of the variable characteristics of the gear occurring during its work (b_r, b_p, b_n, h), and by the variable magnitudes of the linear characteristics of individual variants of the model (1_p, 1_{p1}). The geometrical and geometrical-motional function were calculated by means of the formulae 28 and 29, which contain the linear elements preceding the trawl in relation to the otter-boards, and are more suitable for evaluating the catching capabilities of the tested fishing system than are the qualities of the trawl body construction. The basic work parameter, with which the qualitative evaluation of the pelagic trawl can be derived, is the surface of the mouth of the net. The shape of the mouth of the net of the models trawled on ropes is oval, similar to and ellipse. Its surface is calculated with the formula 26 where, instead of the distance between the otter-boards (b_r), the horizontal spread between the points that connect the head line and the main rope of the side panel of the trawl (b_0) is taken.

The surface of the mouth (S_w), and the geometrical-motional function (G_{zv}) of the body of the tested models have these values:

— for the model variant 2:

$S_w = 41.63\ m^2$

$G_{zv} = 179.6 \times 10^3\ m^3/h$;

— for the model variant 3:

$S_w = 43.70\ m^2$

$G_{zv} = 191.8 \times 10^3\ m^3/h$;

— for the model variant 4:

$S_w = 40.76\ m^2$

$G_{zv} = 178.9 \times 10^3\ m^3/h$.

It follows from the above data that the model variant 3 has the greatest value for the mouth surface and the geometrical-motional function or the quantity of the filtered water in time unit at the approximate trawling speeds ($v_2 = 2.33$; $v_3 = 2.37$; $v_4 = 2.37$ knots), while the smallest value has the model with ropes (variant 4). Although the model variant 4 has the smallest values S_w and G_{zv} it should be pointed out that it has, in relation to other variants, a considerably smaller resistance. Starting from the assumption that the analysed gears are designed for vessels of similar trawling capacities in the case of trawling the model variant 4 it will be possible to increase its size, namely, its trawling speed to realize resistance similar to the two previous models, which is very important for catching fish of great speed of movement.

Because it is possible to atain a smaller hydrodynamic resistance, and at the same time also to increase the size of the elements of the mouth of the gear, in many countries the trawls with ropes are applied more and more in industrial fishery. Under the Adriatic conditions, just for this reason, the construction with a netting of large meshes in the hanging parts of the trawl (elements of the mouth of the trawl) should be used for catching pilchard with pelagic trawls, and also trawls with ropes should be considered.

3.1.5. *Analysis of the constructional-assembling characteristics of the pelagic trawls on the basis of observations and underwater photos*

The most positive side of observing directly the fishing gear is the possibility of correcting and removing immediately and in the phase of testing the imperfections in the work of the gear, which are the result of the constructional errors and of the irregular work of the gear.

Observations and uderwater photographing were conducted on the model variant 1 while trawling it on the poles of the measuring bridge on the catamaran and on the warps, also on the catamaran. The localities of which the underwater photos were taken are shown in Fig. 10.

While trawling the model on the poles of the measuring bridge and on the warps it was stated that the belly of the net has the regular shape of the truncated cone which is getting narrower towards the cod end. The mouth of the belly is a flattened oval, and the shape of the end of the belly, on the spot where it is joined to the cod end, is similar to a circle. The belly of the tested gear was working steadily without any jerks and change of the attacking angle[5]) of the nettinng. A significant characteristic of this construction is the deformation of the netting on the bosom of the head line, the lead line, and the side rope. This is shown by the presence of loose (unburdened) and irregular meshes with almost totally irregular sides. This is illustrated by photos 8, 9, and 10.

The bosom of the mouth of the net was not burdened evenly and the netting in that part of the net was loose and bulging out, the shape of the mesh was irregular. Such deformations of the netting were particularly expressed on the first segment of the belly of th upper and lower part of the trawl, about 10 meshes from the bosom and about 5 meshes from the bosom on the side panel (Photo 11). The deformation of the netting appeared also on the wings. As seen on Photo 12, along the wing selvages there is a row of thickset and deformed meshes, which continue on the wedges of the wings. The sides of the meshes on the wedges of the wings horizontal to the direction of the force actions carry on these forces, while the sides of the meshes vertical to the direction of the force action are loose and do not work. The base of the wedges is curved towards the end of the wing (Photo 14). Towards the central part of the wing the meshes are regularly arranged and deformations disappear. Great deformations of the meshes of the netting appear in the end part of the wing, both in the head line, lead line, and the side panel of the net (Photos 12 and 13). All the mentioned irregularities and deformations affect the size of the horizontal spread of the mesh and also the shaping of the constructional indicators of the net, and the parameters of the mouth. These deformations are caused by the irregular construction and cutting of the wings and wedges, and by the magnitude of the coefficient of the hanging netting. On the basis of the established irregularities in the construction of the model variant 1 (original model), in the model variant 2 the cutting of the wings and the coefficient of the hanging netting were changed, and the wedges in the upper (head line) and the lower (lead line) part of the net were removed (the upper and the lower wings were elongated by 6 meshes and on the whole outer selvage of the wing slanting cutting was was applied instead of the combined one). The observations of the model variant 2, hich was trawled on the poles of the measuring bridge of the catamaran, showed that these changes impoved the construction and that all the irregularities on the parts of the mouth of the net disappeared. As the construction of the wing on the side panel of the model variant 2 was not changed, but remained the same as in the model variant 1, all the irregularities and deformations in that part of the belly remained the same as in the model variant 1. This fact corroborated the hypothesis that all the deformations were caused by the construction of the wings and the magnitude of the coefficient of the hanging netting on the bondary ropes.

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[5] This is the angle between the side selvage and the vertical centreline of the gear. This angle depends on the vertical spread of the net mouth; in pelagic trawl it should be 10—12°, and in the bottom trawls to 25° (Okonski, 1968).

The deformations of the netting, present in the first segment of the belly of the tested model, gradually disappeared in the next segments towards the cod end. The deformations of the netting on the side selvages (seams) of the belly were not present either, which is proven by the Photos 15, 16, 17, 18, and 19. This is a proof of the correct cutting and assembling these parts of the net.

The angle of attack on the belly along its whole length was about 14° to 12°, while on the cod end it was somewhat smaller.

3.2. Analysis of the resistance characteristics of pelagic trawls

At testing, the resistance of the body of the model was determined in relation to the spread coefficient of the head line (λ_n), side rope (λ_b), and hauling depth of the pole of the catamaran measuring bridge (z_w) at variable trawling speeds, and the trawling system at variable trawling speeds and at various lengths of the released warps.

3.2.1. *Analysis of the body resistance of the tested models*

The measurements of the trawl body resistance trawled on the poles of the measuring bridge of the catamaran were carried out on the models variant 1 and 4. Tables 7 and 8 show the results for the model variant 1 at different coefficients of the spread of the head line, side rope, hauling depth

Table 7. Resistance of the pelagic trawl model — variant 1, not rigged and spread on the short poles of the catamaran, at variable trawling speeds

Measure No.	Trawling speed v m/s	knots	Left pole resistance upper kG	lower kG	Right pole resistance upper kG	lower kG	Total R kG
			$\lambda_n = 0.445$		$\lambda_b = 0.319$		$z_w = 3.00$ m
1	0.60	1.16	7	7	9	10	33
2	0.80	1.55	12	12	13	16	53
3	1.05	2.04	22	19	20	23	84
4	1.20	2.33	29	30	30	33	122
6	1.50	2.91	42	36	40	44	162
7	1.65	3.20	48	49	49	60	206
8	1.70	3.30	52	52	50	58	212
			$\lambda_n = 0.351$;		$\lambda_b = 0.319$;		$z_w = 3.00$ m
1	0.55	1.06	3	3	3	3	12
2	0.60	1.16	5	5	5	5	20
3	0.70	1.36	7	10	7.5	8	32.5
4	0.80	1.55	9	12.5	9	12	42.5
5	0.90	1.74	9.7	16.5	13.5	17	56.7
6	1.00	1.94	9	17	17	21	64
7	1.05	2.04	17	18	17.5	20	72.5
8	1.10	2.13	13	21	17.5	23	74.5
9	1.20	2.33	17.5	25	21	26.5	90
10	1.30	2.52	22	28.5	24.5	31.5	106.5
11	1.40	2.72	29	33.5	26	32.5	121
12	1.50	2.91	33	35	33.5	37	138.5
13	1.60	3.10	37	39.5	35	41.5	153
14	1.70	3.30	41	42.5	39	44.5	167

of the poles of the measuring bridge, and the trawling speed, and for the model variant 4 this is seen in Table 9, while Graph 2 illustrates their graphic presentation. It follows from Tables 7, 8 and 9, and Graph 2 that the least

Table 8. Resistance of the pelagic trawl model — variant 1. rigged and spread on the long poles of the catamaran, at variable trawling speed

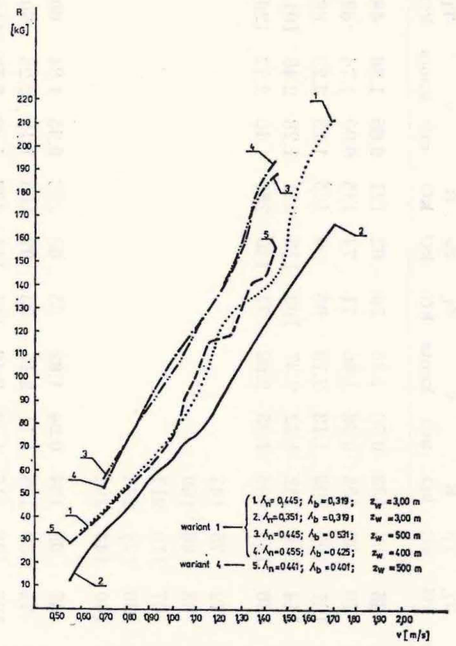
Measure No.	Trawling speed v m/s	knots	Left pole resistance upper kG	lower kG	Right pole resistance upper kG	lower kG	Total R kG
			$\lambda_n = 0.445$		$\lambda_b = 0.531$		$z_w = 5.00$ m
1	0.70	1.36	15	13.5	15	12	55.5
2	0.80	1.55	20	17	20	15.5	72.5
3	0.90	1.74	23	23	25	19,5	90.5
4	1.00	1.94	27.5	26.5	30	25	109
5	1.15	2.23	33	34.5	30	30	127.5
6	1.25	2.42	38.5	37.5	37	38.5	151.5
7	1.35	2.62	43	46	40	46	175
8	1.45	2.81	44.5	48.5	46	49.5	188.5
			$\lambda_n = 0.445$;		$\lambda_b = 0.425$;		$z_w = 4.00$ m
1	0.70	1.36	13.5	12	15	11.5	52
2	0.80	1.55	19.5	17.5	21	15.5	73.5
3	0.90	1.74	23.5	21	24	18.5	87
4	1.00	1.94	27.0	30	31	25	113
5	1.15	2.23	32.0	31.5	33	32	128.5
6	1.25	2.42	35.0	36	38	34	143
7	1.35	2.62	43.0	42.5	45	46	176.5
8	1.45	2.81	49.0	49	48	48	194

Table 9. Resistance of the body of the pelagic trawl model with ropes — variant 4, rigged and spread on the long poles of the catamaran, at variable trawling speeds

Measure No.	Trawling speed v m/s	knots	Left pole resistance upper kG	lower kG	Right pole resistance upper kG	lower kG	Total R kG
			$\lambda_n = 0.441$		$\lambda_b = 0.401$		$z_w = 5.00$ m
1	0.55	1.06	5.1	6.8	8.4	7.5	27.8
2	0.70	1.36	7.9	11.7	10.4	11.3	41.3
3	0.90	1.74	13.6	19.6	13.3	14.7	61.2
4	1.00	1.94	15.2	22.4	18.8	18.8	75.2
5	1.05	2.04	22.2	24.6	22.8	21.6	91.2
6	1.10	2.13	20.8	29.9	24.4	26.3	101.4
7	1.15	2.23	29.9	30.1	26.6	29.1	115.7
8	1.25	2.42	26.4	35.9	26.5	29.7	118.2
9	1.35	2.62	30.6	42.3	31.8	37.6	142.3
10	1.40	2.72	31.2	39.9	32.5	38.5	142.1
11	1.45	2.81	34.8	45.1	34.8	41.4	156.1

resistance was realized by the model variant 1, which was trawled at $\lambda_n = 0.351$, $\lambda_b = 0.319$, $z_w = 3.00$ m (Curve No. 2) and $\lambda_n = 0.445$, $\lambda_b = 0.319$, $z_w = 3.00$ m (Curve No. 1), and by the model variant 4 at $\lambda_n = 0.441$, $\lambda_b = 0.401$, $z_w = 5.00$ m (Curve No. 5). It should be mentioned that the Curves Nos 1 and 2 refer to the model variant 1 which was not rigged, therefore resistances are somewhat smaller (for the elements of riginng) than are the ones shown on the Curves Nos 3 and 4. The results shown on the Curves

Nos 3 and 4 are also obtained at a larger spread of the side rope (greater hauling depth of the poles). The increased spread of the side rope increased the vertical spread of the mouth of the belly at retaining the same horizontal spread. This resulted in the increase of the mouth surface of the trawl



Graph 2. Dependence of the resistance of the bodies of the pelagic trawl models on trawling speed.

body. It should be pointed out that the increased geometrical-motional function of the trawl body corresponds to the increased resistance, which means a greater quantity of filtered water in a time unit. The body of the pelagic trawl model with ropes, trawled with aproximate coefficients of the spread of the head line and the side rope and the vertical spread, shows a considerably smaller spread than does the model with the elements of the mouth of the belly constructed of netting. The curve on Graph 2 shows clearly that the model with ropes with approximate magnitudes of the mouth of the belly has a considerably smaller resistance than has the model whose elements of the mouth are made of netting.

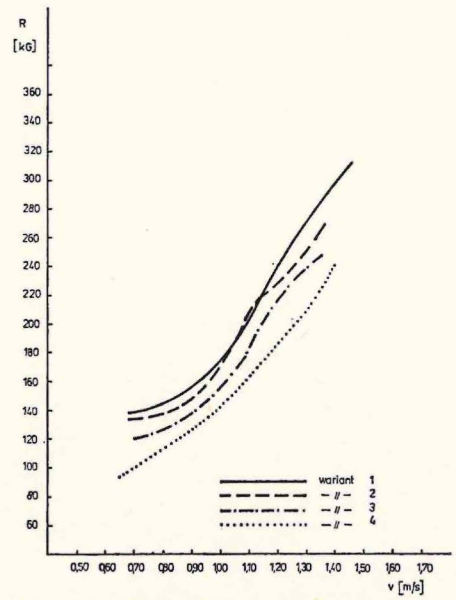
3.2.2. *Analysis of the trawling system resistance of the tested models*

The results of the measurements of the resistance of the trawling system of the analysed pelagic trawl models which were trawled by the catamaran and the vessel at variable trawling speeds and lengths of the released warps are shown in Table 10. On the catamaran the model variant 1 was trawled,

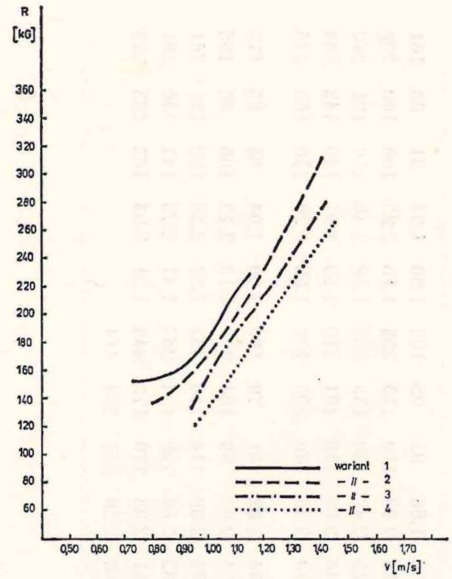
Table 10. Resistance of the trawling system of the pelagic trawl models at variable trawling speeds and different lengths of released warps

Mesure No.	Lenght of released warps	Variant 1					Variant 2					Variant 3					Variant 4				
		Trawling speed		Warp tension left	right	total	Trawling speed		Warp tension left	right	total	Trawling speed		Warp tension left	right	total	Trawling speed		Warp tension left	right	total
	l_t m	v m/s	knots	T_L kG	T_P kG	R kG	v m/s	knots	T_L kG	T_P kG	R kG	v m/s	knots	T_L kG	T_P kG	R kG	v m/s	knots	T_L kG	T_P kG	R kG
1	30	0.68	1.32	38	70	138	0.68	1.32	65	68	133	0.70	1.36	59	62	121	0.65	1.26	46	47	93
2	30	0.98	1.90	82.5	85.5	168	0.96	1.86	78	80	158	0.96	1.86	71	74	145	0.90	1.74	62	65	127
3	30	1.13	2.19	106	108	214	1.10	2.13	101	105	206	1.13	2.19	96	99	195	1.15	2.23	88	88	176
4	30	1.22	2.37	119.2	123.8	243	1.22	2.37	114	118	232	1.22	2.37	109	112	221	1.28	2.48	101	103	204
5	30	1.36	2.64	138.8	150	288.8	1.36	2.64	130	138	268	1.35	2.62	127	130	257	1.40	2.72	120	123	243
1	40						0.70	1.36	72	75	147										
2	40						0.94	1.82	83	86	169										
3	40						1.10	2.13	107	110	217										
4	40						1.22	2.37	120	124	244										
5	40						1.32	2.56	140	144	284										
1	50	0.73	1.41	75	75	150	0.80	1.55	65	69	134	0.94	1.82	65	68	133	0.95	1.84	60	60	120
2	50	0.94	1.82	83	84	167	0.94	1.82	75	80	155	1.11	2.15	93	97	190	1.15	2.23	90	88	178
3	50	1.03	2.00	96	98	194	1.15	2.23	107	108	215	1.28	2.48	114	118	232	1.30	2.52	110	110	220
4	50	1.15	2.23	113	115	228	1.40	2.72	153	156	309	1.32	2.56	121	125	246	1.38	2.68	120	125	245
5	50											1.42	2.76	138	142	280	1.45	2.81	130	135	265
1	60						0.94	1.82	85	89	174										
2	60						1.13	2.19	110	113	223										
3	60						1.38	2.68	153	156	309										
4	60						1.51	2.93	165	171	336										
5	60						1.68	3.26	201	204	405										

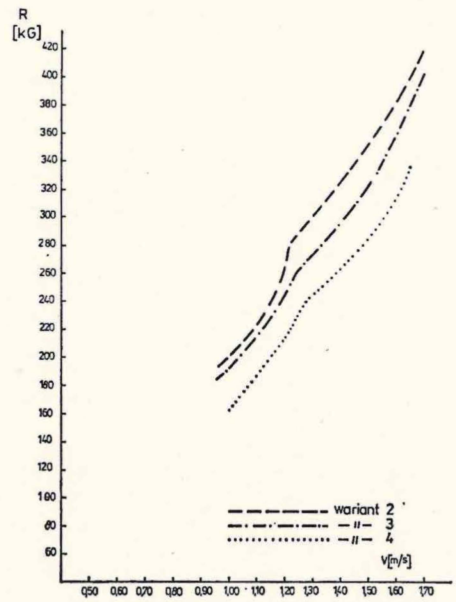
1	80	0.96	1.86	96	98	194	0.96	1.86	91	95	186	1.00	1.94	81	80	161
2	80	1.14	2.21	116	120	236	1.15	2.23	110	115	225	1.15	2.23	100	100	200
3	80	1.22	2.37	139	140	279	1.25	2.42	130	133	263	1.28	2.48	119	121	240
4	80	1.46	2.83	168	170	338	1.46	2.83	158	161	319	1.50	2.91	140	143	283
5	80	1.69	3.28	208	209	417	1.70	3.30	199	203	402	1.65	3.20	170	165	335
1	100	1.12	2.17	120	124	244	0.94	1.82	81	79	160	1.00	1.94	85	85	170
2	100	1.25	2.42	142	145	287	1.04	2.02	99	104	203	1.10	2.13	100	96	196
3	100	1.35	2.62	160	166	326	1.23	2.39	114	118	232	1.32	2.56	120	121	241
4	100	1.50	2.91	178	183	361	1.32	2.56	129	134	263	1.41	2.73	141	140	281
5	100	1.70	3.30	213	216	429	1.51	2.93	170	173	343	1.51	2.93	162	163	325
6	100						1.68	3.26	205	209	414					



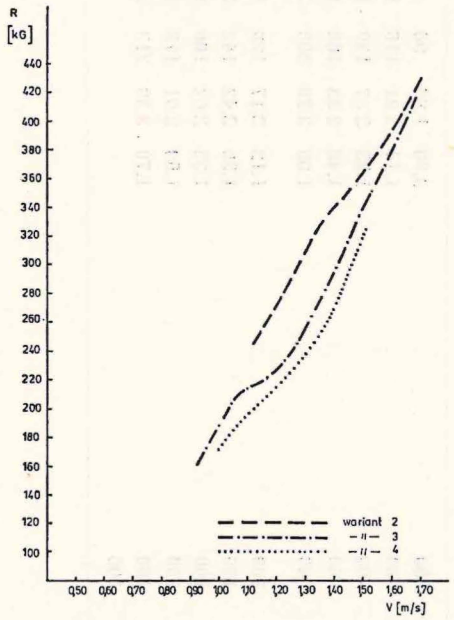
Graph 3. Dependence of the resistance of the pelagic trawls on trawling speed at 30 m of released warps.



Graph. 4. Dependence of the resistance of the pelagic trawls on trawling speed at 50 m of released warps.



Graph 5. Dependence of the resistance of the pelagic trawls on trawling speed at 80 m of released warps.



Graph 6. Dependance of the resistance of the pelagic trawls on trawling speed at 100 m of released warps.

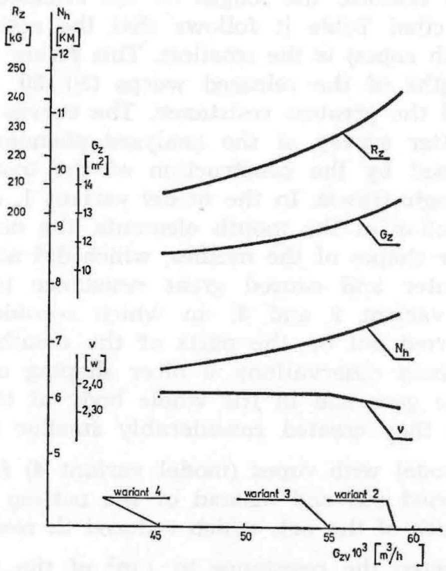
where, for technical reasons, the length of the released warps was limited to 50 m. From the cited Table it follows that the resistance of the model variant 4 (model with ropes) is the smallest. This refers also to all the trawling speeds and lengths of the released warps (30, 50, 80, and 100 m). The model variant 1 had the greatest resistance. The curves on the Graphs 3, 4, 5, and 6 give a better survey of the analysed phenomena. Such values of resistance were caused by the construction of the mouth elements of the tested models of pelagic trawls. In the model variant 1, due do the imperfections in the construction of the mouth elements, the netting of this part of the net had irregular shapes of the meshes, which did not ensure corresponding filtration of water and caused great resistance in the hydrodynamic sense. The models variant 2 and 3, on which considerable constructional alterations were carried out on the parts of the mouth, were characterized by, as proved by direct observations, a nicer shaping of the netting in the hanging parts of the gear and in the whole body of the trawl, and in the hydrodynamic sense they created considerably smaller resistance.

On the trawl model with ropes (model variant 4) further constructional alterations were carried out and instead of the netting ropes were used on the parts of the mouth of the net, which reduced th resistance of the model.

To a certain degree the resistance to 1 m^2 of the trawl mouth surface also reflects the analysed phenomenon. These magnitudes are presented in this way:

model variant 2 — 5.82 kG/m^2 of mouth surface,
model variant 3 — 5.23 kG/m^2 of mouth surface,
model variant 4 — 5.07 kG/m^2 of mouth surface.

At analysing the resistance of the trawling system the resistance should be collated with the values of the geometric and geometrical-motional function. Graph 7 shows the values of the characteristics, trawling speed, resistance and tow-rope power for different geometrical-motional function of the pelagic trawl models variants 2, 3, and 4. The geometrical and geometrical-motional function were calculated on the basis of the mean values of the horizontal and vertical spreads and the trawling speed, and the trawling powers were calculated on the basis of the mean values of resistance and trawling speed of the analysed variants of the pelagic trawl models. By analysing the variability of individual magnitudes on Graph 7, it can be concluded that the increase of penetration or of the geometrical-motional function cause the increase of resistance (R_z) and of the tow-rope power (N_h). The increase of the geometrical-motional function requires the increase of the towing-power, which means also the power of the main driving engine. It should be pointed out that in this case the resistance does not increase only with the square value of the trawling speed but also proportionately with the thickness and construction of individual parts of the net, especially of the contracting elements, namely the mouth elements, which depends particularly on the thickness of the twine and the size of the netting mesh of individual fishing gears.



Graph 7. Geometric function, trawling speed, resistance and trawling power of the trawling system of the pelagic trawl models.

4. CONCLUSION

4.1. On the basis of direct underwater observations and analysis of the undewater photos it was stated that considerable irregularities in the construction of the parts of the mouth of the tested pelagic trawl models exist. The alterations improved the pelagic trawl models variants 2, 3, and 4, which had then a better shape of the netting and better hydrodynamic characteristics. The deformations of the netting that appeared on the wing parts of the mouth resulted from the combined cycle of cutting used mainly at cutting the trawling fishing gear. When the combined cycle of cutting was replaced by the slanting one, the deformations on the netting were eliminated.

4.2. The coefficient of the horizontal spread of the mesh (u_x) has different values in each element of the pelagic trawl, which become smaller towards the cod end. On the basis of these values, we can foresee the shaping of the netting in the fishing gear.

4.3. Among the analysed models, regarding the shaping of the mouth and of individual elements of the body of the pelagic trawls, the model with ropes (variant 4) is the most suitable one for catching the bottom and dispersed shoals of pilchard, because of its elliptical shape of the mouth.

4.4. The increased speed of trawling increases the horizontal spread of the mouth, and at the same time, the vertical spread decreases. The model with ropes has the largest mean horizontal spread.

4.5. The model variant 4, whose netting in the parts of the mouth was replaced by ropes, has the least resistance of all the analysed pelagic trawls. Such a construction of the mouth caused reduced resistance.

4.6. The increasd geometrical-motional funnction which corresponds to the size of the penetrated water body covered by the tested trawling system causes increased resistance and tow-rope power. Resistance and tow-rope power increases gradually, which follows from the netting with large meshes and the ropes in the mouth elements of the tested models.

4.7. On the basis of direct underwater observations and by means of photo documentation it was possible to conduct and evaluate precise analysis of the shaping and construction of the models of the pelagic trawl bodies, and the regularity of their work. The model tests confirm the efficiency of the described technique of trawling by catamaran. By trawling the models by catamaran and by conducting direct underwater observations it is possible to follow the work of the tested gear, and to notice quickly the possible constructional irregularities which can be removed immediately in the phase of testing. This method is very suitable for testing the trawling fishing gear, therefore all the newly constructed bottom and pelagic trawls should be verified by the described test technique.

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ANALIZA KONSTRUKCIJA I OTPORA LEBDEĆIH KOČA ZA ULOV SRDELE U JADRANU NA TEMELJU ISPITIVANJA MODELA I PODVODNIH PROMATRANJA

Perica Cetinić[1] i Jozef Swiniarski[2]

[1] *Institut za oceanografiju i ribarstvo, Split*

[2] *Faculty of Sea Fishery and Nutrition Technology, Institute of Aquiculture and Fishing Technique, Szczecin*

KRATAK SADRŽAJ

Autori su izvršili analizu konstrukcija i otpora lebdećih koča, namjenjenih ulovu srdele i ostalih vrsta male plave ribe u Jadranu na temlju ispitivanja modela i podvodnih promatranja. Ispitivani su modeli lebdeće koče 32/37 × 17/22, koja je izrađena u skali 1 : 2 u četiri varijante, koje se među sobom razlikuju konstrukcijom elemenata djelova usta alata. Ispitivane varijante modela su imale od 2 segmenta grla prema vreći istu konstrukciju i sve preinake su vršene na krilima i prvom segmentu grla. Ispitivanja su vršena povlačenjem modela pomoću mjernog mosta koji je sagrađen kao katamaran i istraživačkog broda. U ispitivanjima je korištena ova mjerna aparatura: brzinomjeri, dinamometri, kutomjer i dubinografi.

Tokom ispitivanja vršena su mjerenja različitih parametara kao: brzina kočarenja (v), sila napetosti (T), kutevi loma (α) i razmicanje (r) povlačne užadi, utonuće plutnje (g_n) i olovnje (g_p), dužina ispuštene povlačne užadi (1_t) te dužina stranica (a) i vodoravnih dijagonala oka (x) mrežnog tega. Također su vršena podvodna promatranja i fotografska snimanja ponašanja alata i oblikovanja tijela koče pod vodom. Osim parametara koji su dobiveni neposrednim mjerenjem, izračunavane su ove veličine: okomiti raspon usta grla koče (h), pokazatelji vodoravnog raspona koče kao rasponi između točaka koje povezuju plutnju i glavno uže na bočnoj strani koče (b_o), krajeva bočnih rubova (b_n), usta grla (b), plutnje (b_n) i olovnje (b_d), udaljenost između širilica (b_r), geometrijska (G_z) i geometrijsko-pokretna značajka (G_{zv}), koeficijenti raspona plutnje (λ_n), olovnje (λ_d) i povlačnog sustava (λ_z) koeficijenti poprečnog raspona oka mrežnog tega na ustima grla koče (u) i poprečnog otvora oka mrežnog tega u pojedinim djelovima tijela mreže (u_x) te otpor (R_z) i snaga povlačenja (N_h).

Rezultate mjerenih veličina, izračunavane linearne parametre i otpore povlačenja ispitivanih modela prikazuju tabele 1, 2 i 3. Vrijednosti geometrijske i geometrijsko-pokretne značajke, snage povlačenja i konstrukcijskih pokazatelja ispitivanih alata prikazuje tabela 4 i grafikoni 1 i 7. U tabelama 5 i 6 iznose se koeficijenti vodoravnog raspona oka u pojedinim djelovima tijela mreže modela varijante 1, koji su određeni analizom podvodnih fotografija.

Izravnim podvodnim promatranjima i podvodnim snimanjima koje ilustriraju fotografije od 8—19, izvršena je analiza konstrukcijsko-montažnih

osobina lebdeećih koča. Rezultate ispitivanja otpora alata ilustriraju tabele od 7—10 i grafikoni od 2—6.

Na osnovi izravnih podvodnih promtranja i analizom podvodnih fotografija, utvrđeni su znatni nedostaci u konstrukciji dijelova usta ispitivanih modela lebdećih koča. Na osnovi izvršenih izmjena, popravljeni modeli lebdećih koča varijanata 2, 3. i 4. odlikovali su se boljim oblikovanjem mrežnog tega i boljim hidrodinamičkim osobinama. Deformacije mrežnog tega koje su nastale u krilnim dijelovima usta proizlaze iz primjene kombiniranog ciklusa krojenja. Kada se kombinirani ciklus krojenja zamjenio kosim, deformacije na mrežnom tegu su eliminirane.

Koeficijent vodoravnog raspona oka (u_x) ima u svakom elementu lebdeće koče različite vrijednosti, koje se u pravcu vreće smanjuju. Na osnovi tih vrijednosti, može se predvidjeti oblikovanje mrežnog tega u ribolovnom alatu.

Između analiziranih modela, u pogledu oblikovanja usta i pojedinih elemenata tijela lebdećih koča, najpodesniji za ulov pridnenih i raspršenih jata srdele je model s užadima (varijanta 4), koji se odlikuje eliptičkim oblikom usta. Također, i u pogledu otpora najmanji ima model varijante 4, pri kojemu je mrežni teg u dijelovima usta zamijenjen užadima. Takva konstrukcija usta uzrokovala je smanjenje otpora.

Porast brzine kočarenja uzrokuje povećanje vodoravnog raspona usta pri istodobnom smanjenju okomitog raspona. Najveći srednji vodoravni raspon ima model s užadima.

Porast geometrijsko-pokretne značajke koja odgovara veličini penetriranog vodenog prostora obuhvaćenog ispitivanim povlačnim sustavom uzrokuje povećanje otpora i snage povlačenja, koje je postepeno, što proizlazi iz primjene mrežnog tega velikih oka i užadi u elementima usta ispitivanih modela.

Navedena metoda ispitivanja omogućava preciznu analizu oblikovanja i konstrukcije modela tijela ispitivanih alata te pravilnosti njihovog rada. Povlačenje modela pomoću katamarana i obavljanja izravnih promatranja pod vodom omogućava praćenje rada ispitivanog alata, te brzo uočavanje eventualnih konstrukcijskih nepravilnosti, koje se već u samoj fazi ispitivanja mogu ukloniti.

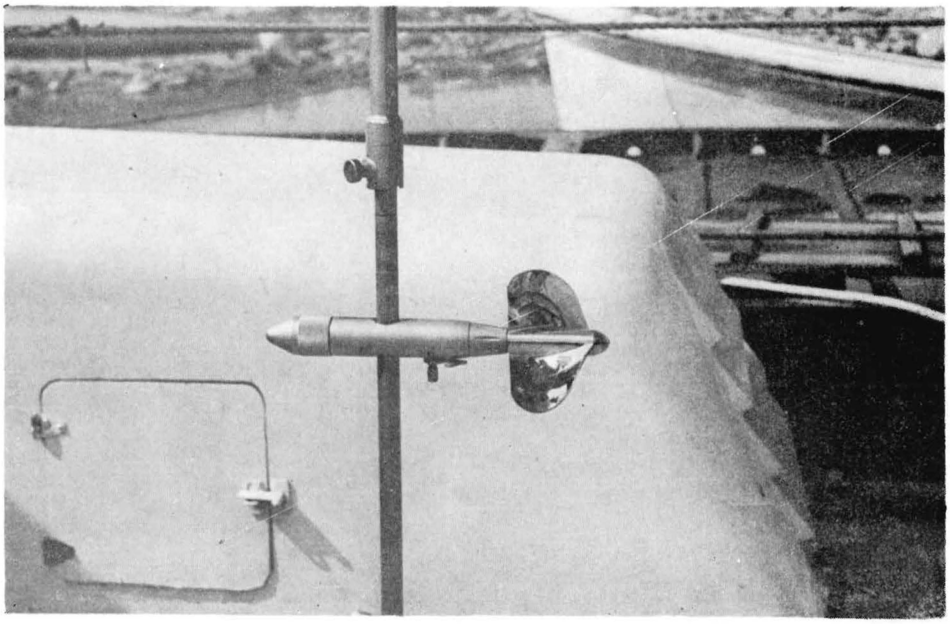


Photo 1. Speedometer used on the catamaran

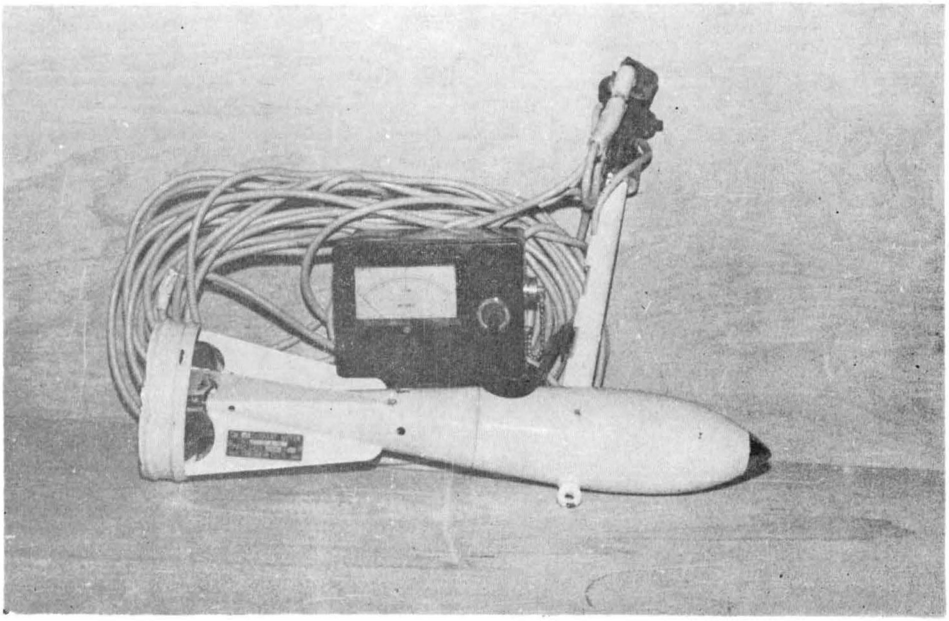


Photo 2. Speedometer used on the vessel

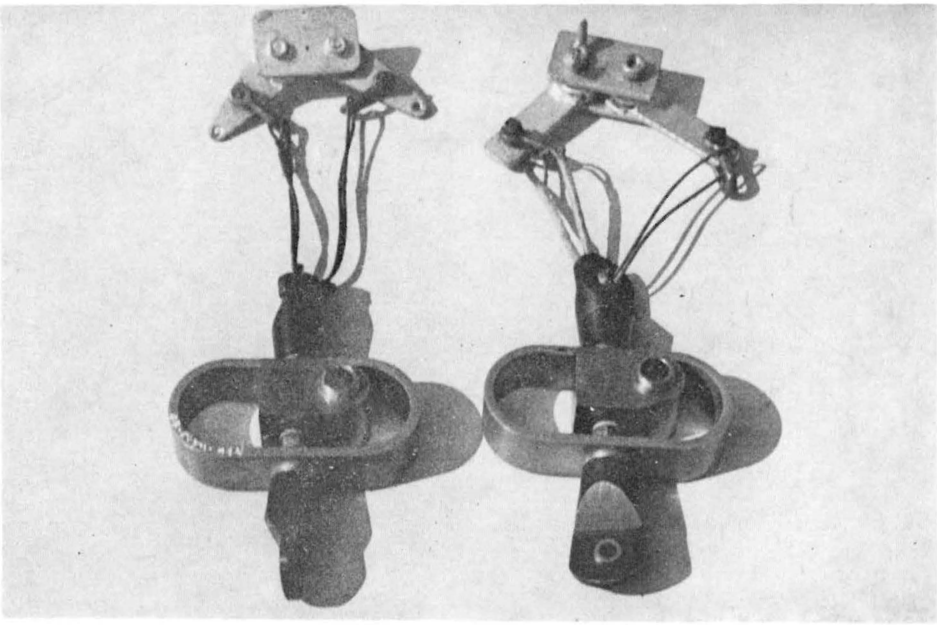


Photo 3. Electric dynamometers

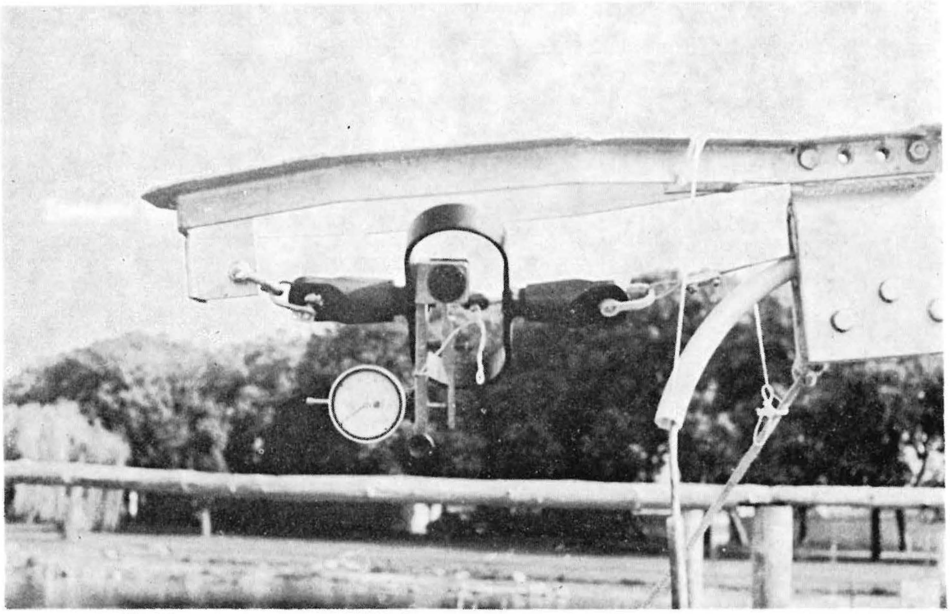


Photo 4. Load indication bridles

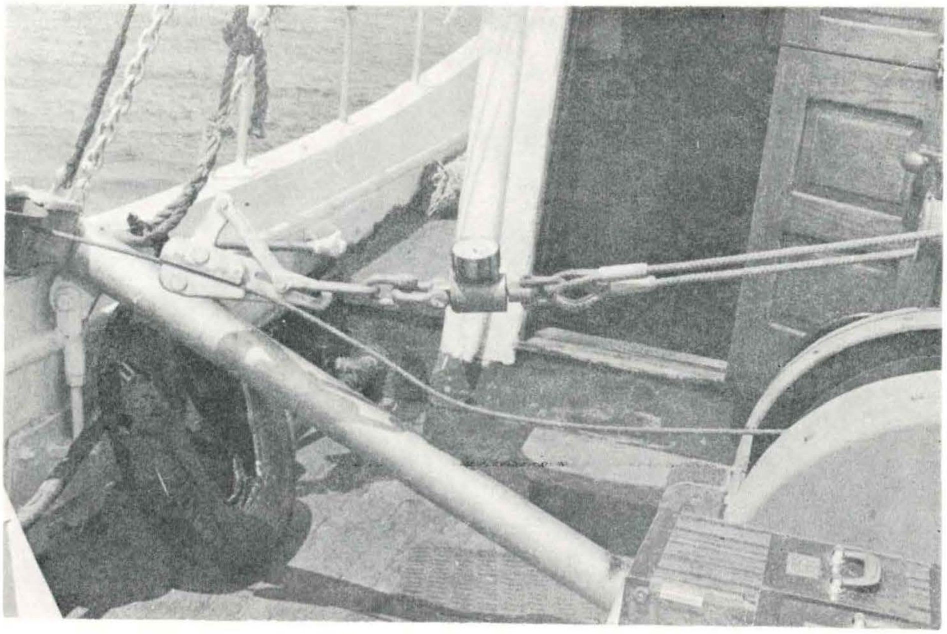


Photo 5. Hidraulic dynamometer

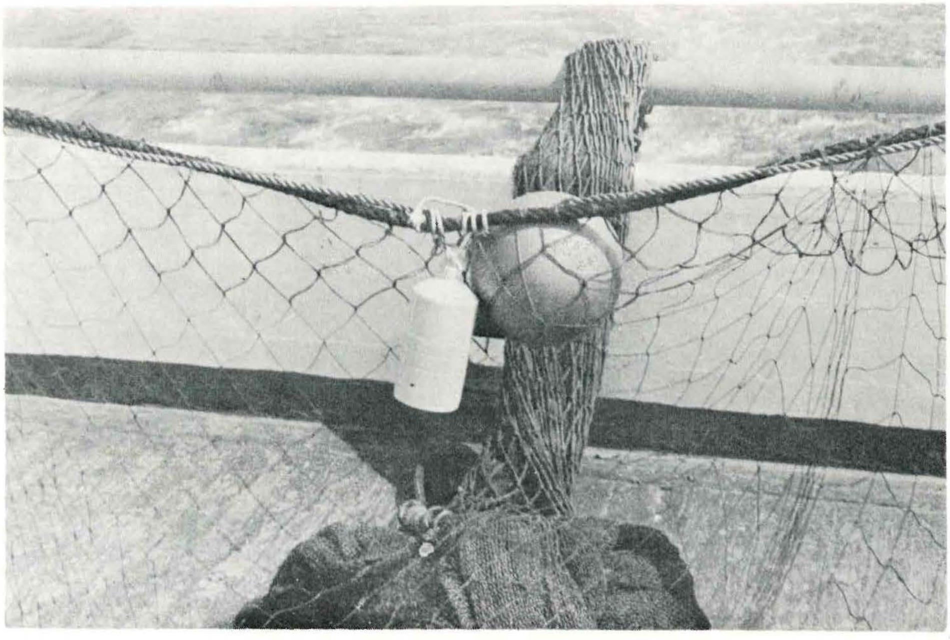


Photo 6. Depthograph on the trawl head line

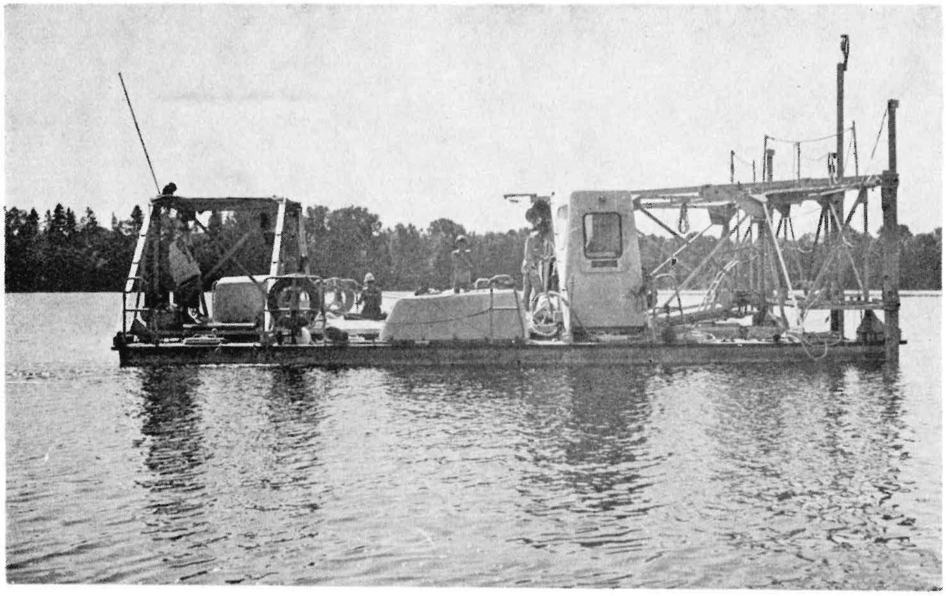


Photo 7. Measuring bridge of the catamaran type

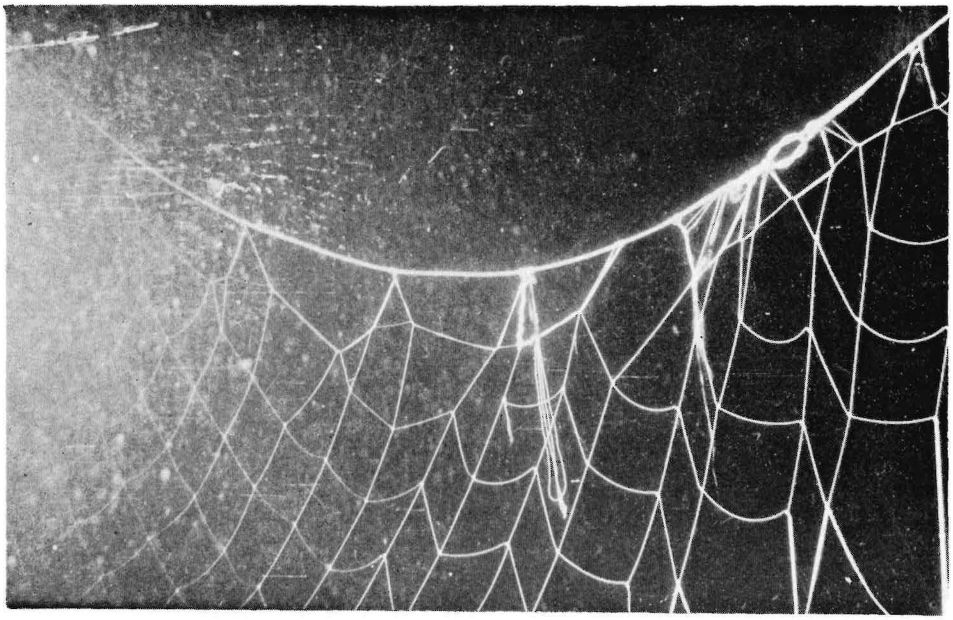
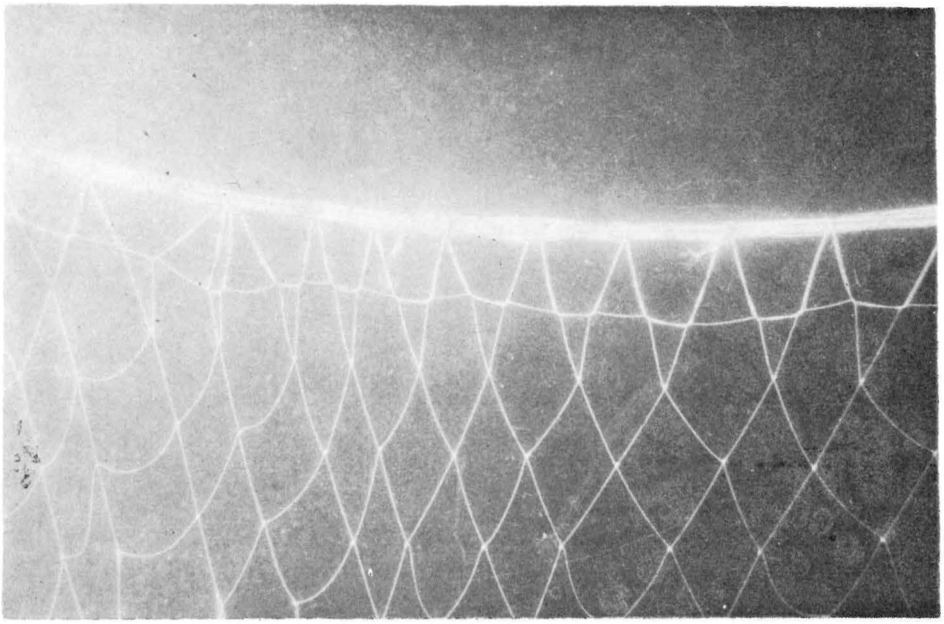
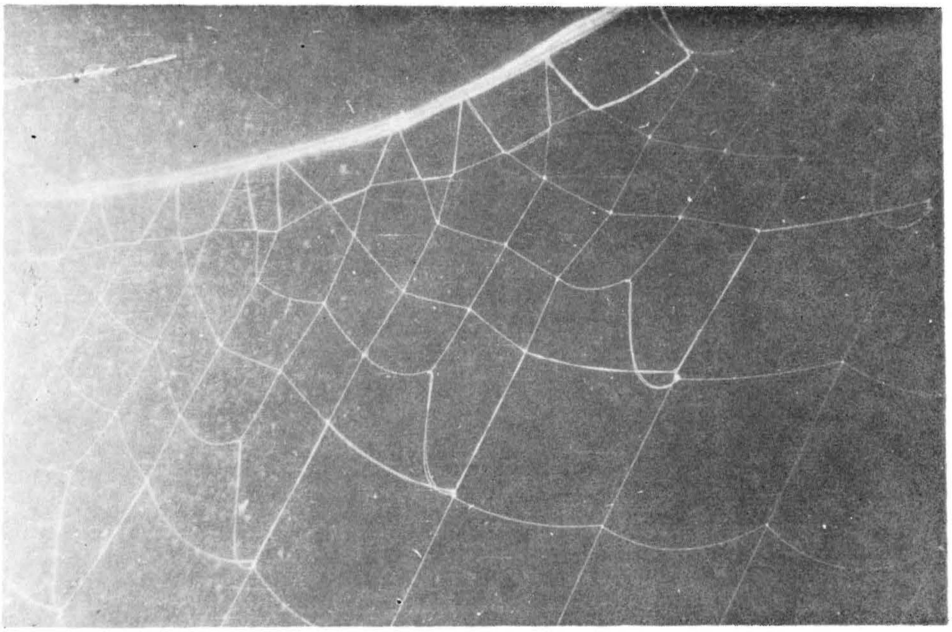


Photo 8. Netting deformation on the bosom of the side panel of the trawl





Photos 9 and 10. Bosom of the lead line with the netting of loose and irregular meshes

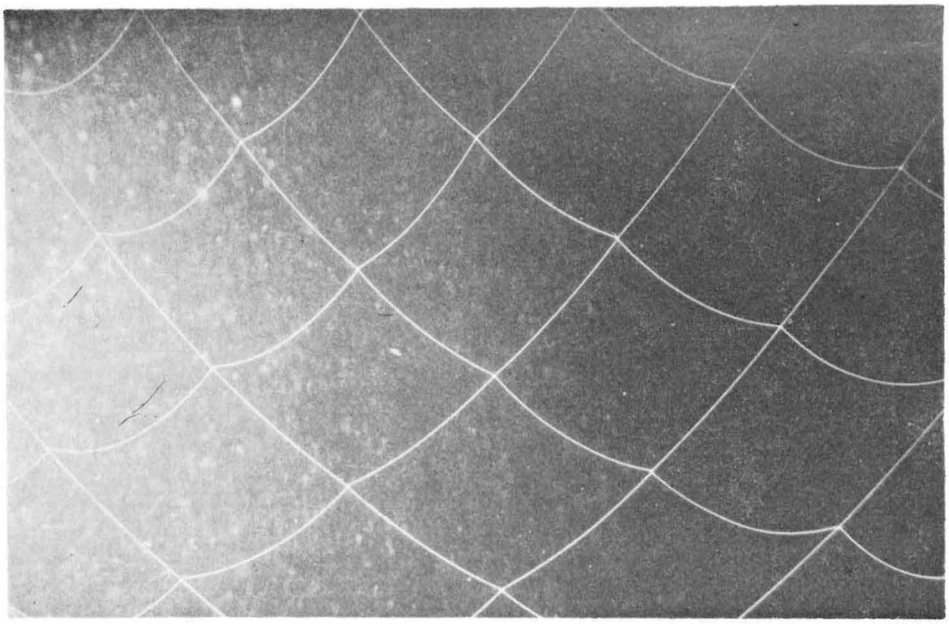
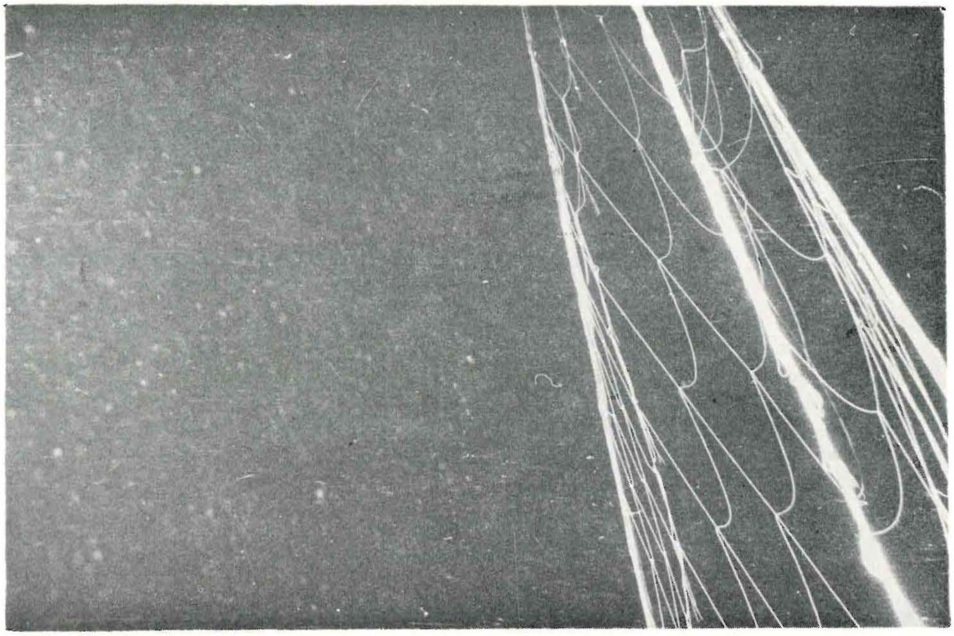
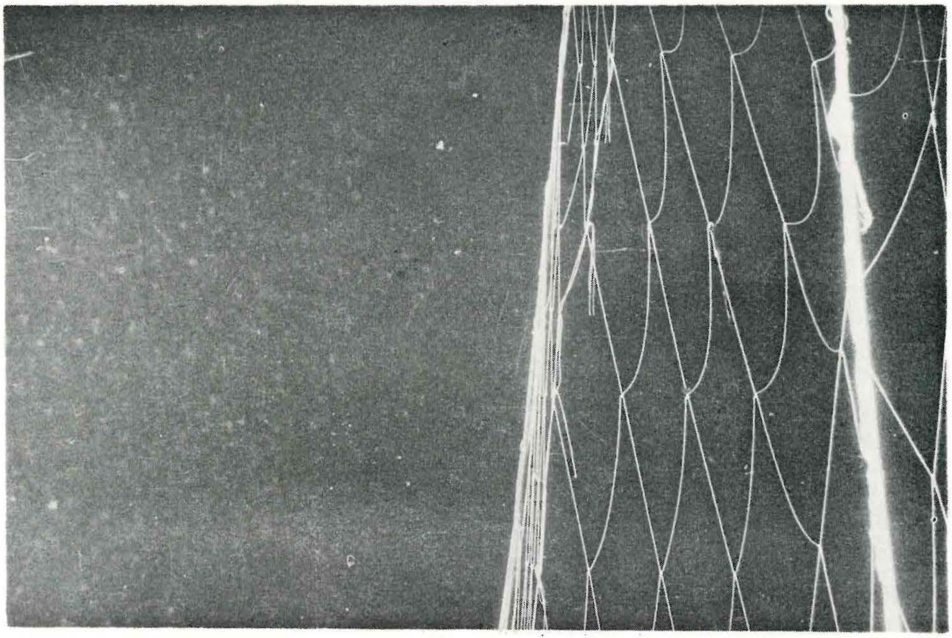


Photo 11. Netting deformation on the first segment of the upper panel of the trawl belly





Photos 12 and 13. Netting deformation on the trawl wings

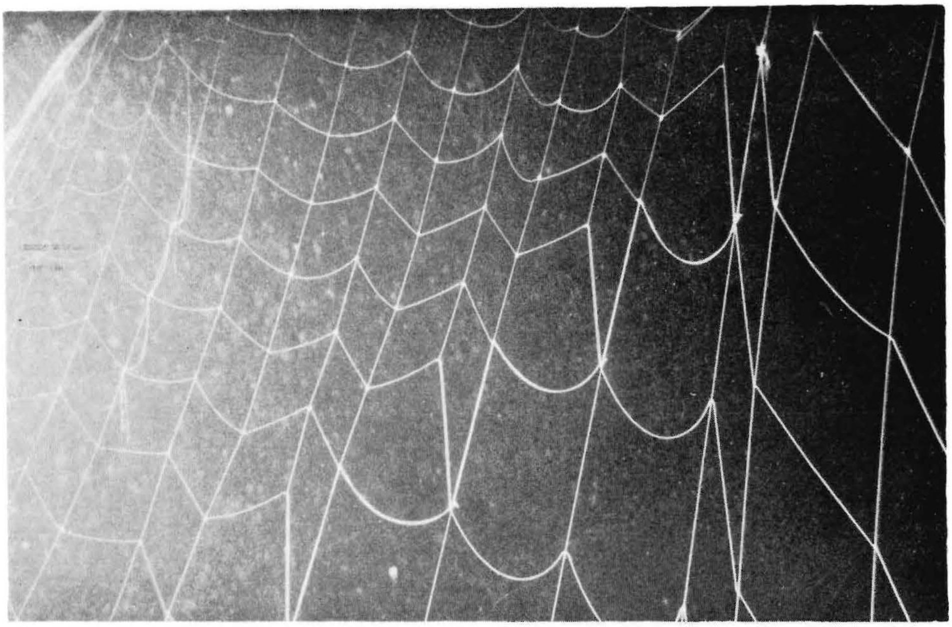


Photo 14. Netting deformation on the spot where wedges are joined to wings. The base of the wedges is bent towards the end of the wing

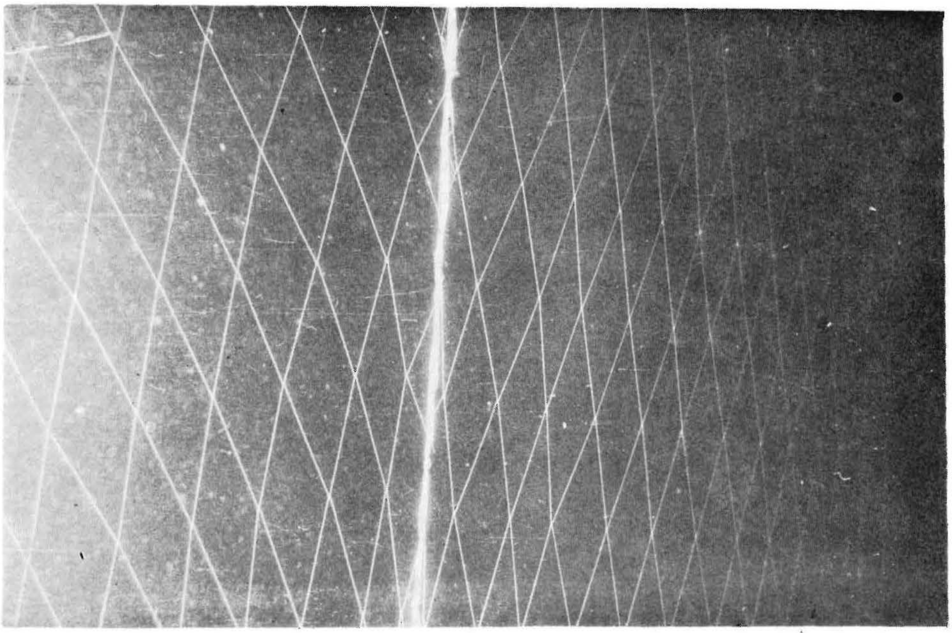


Photo 15. 2nd segment of the belly. Place where the side and the upper panels of the trawl are joined (C-K)

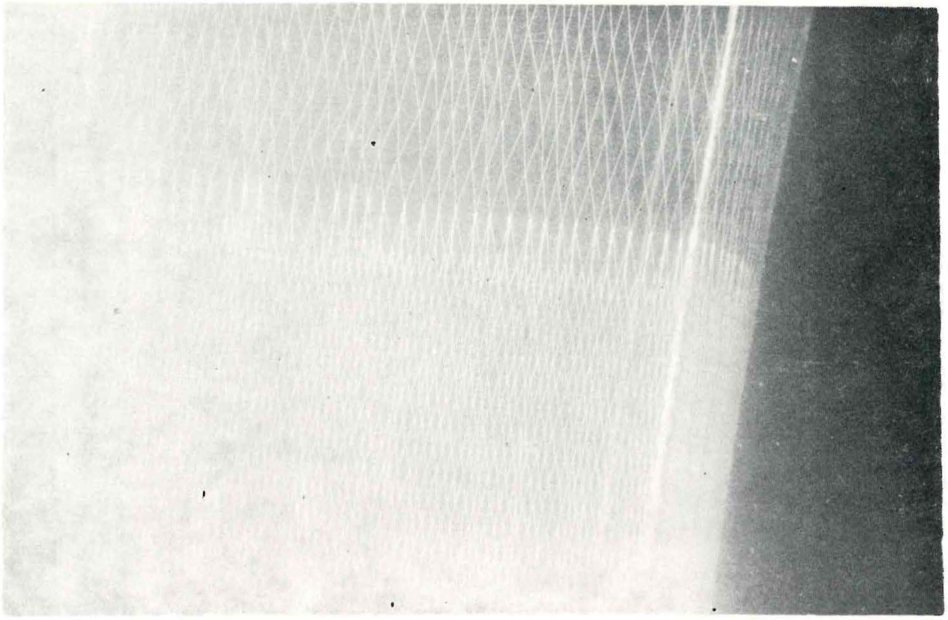


Photo 16. Joining of 4th and 5th segment of the belly of the trawl upper panel (E—F)

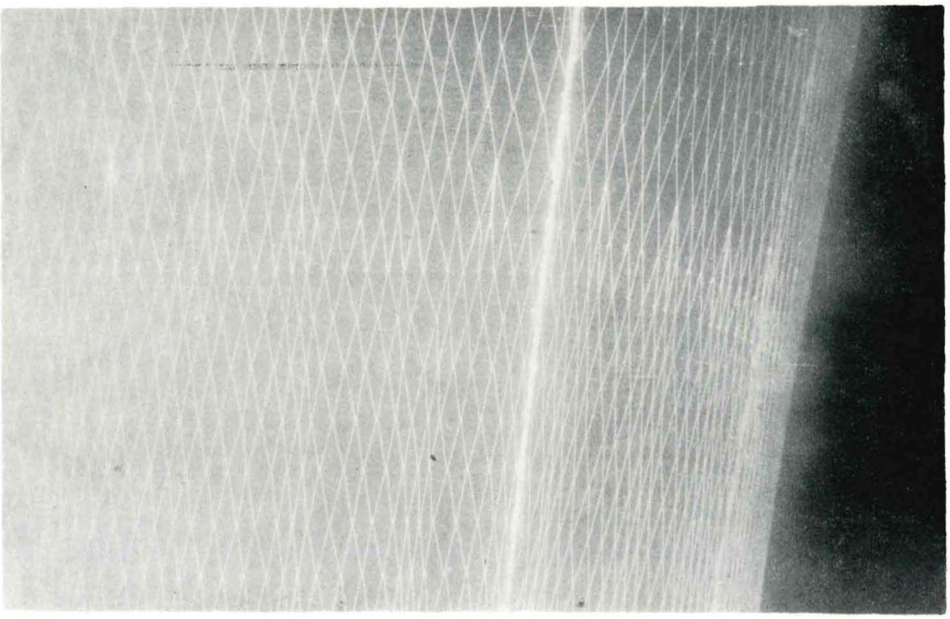


Photo 17. Seam of 3rd and 4th segment of the belly (D—E, L—M) of the upper and side panels of the trawl

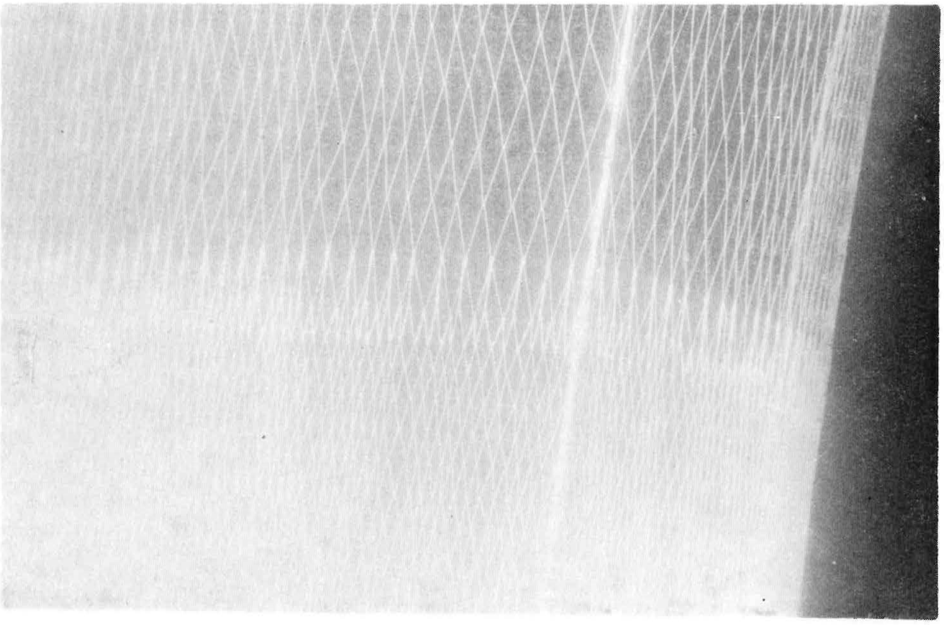


Photo 18. Seam of 4th and 5th segment of the belly (E—F, M—F_1) of the upper and side panels of the trawl

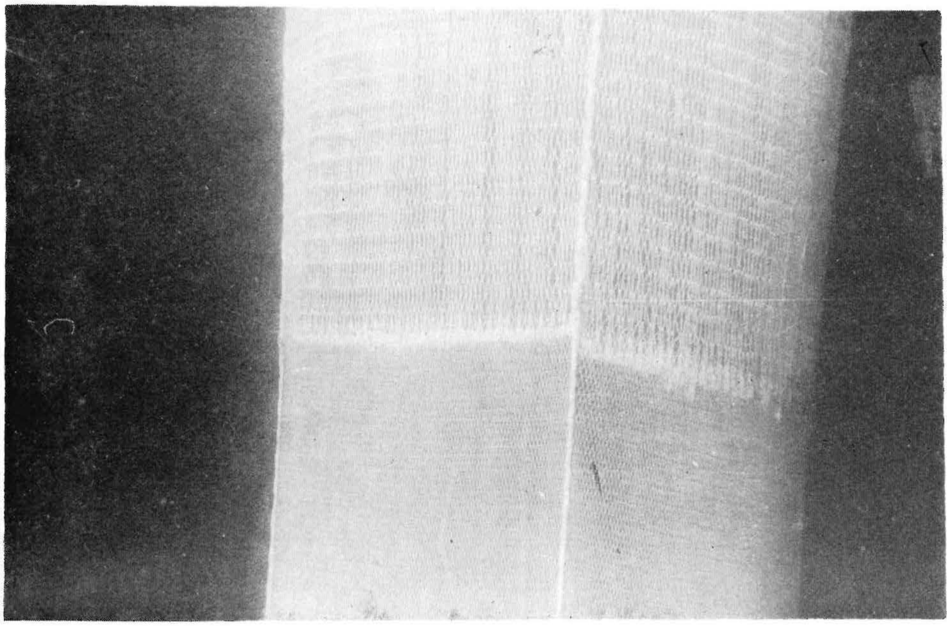


Photo 19. Joining the belly with the codend