TADEUSZ SZELANGIEWICZ, Assoc.Prof.,D.Sc.,N.A.
Technical University of Szczecin
Faculty of Maritime Technology

Designing of mooring positioning system for an existing salvage ship

SUMMARY

In designing the mooring positioning system of the ship two basic requirements for limitation of the ship displacements and mooring wire strength are to be complied with. Apart from these conditions, additional technical service requirements are also imposed.

It is quite easy to observe the additional requirements for the mooring positioning system to be fitted on a new ship. However, ensuring compliance with the requirements for the existing ship, especially small one, is a difficult task and therefore some optimizing calculations are then necessary.

This paper describes design of the mooring positioning system for a small salvage ship. Working out of the project required the system to be adapted to the ship parameters.

INTRODUCTION

When designing the mooring positioning system of the ship the following two basic requirements are to be complied with :

$$r_{C(A)max} \leq r_{(A)dop} \quad (1)$$

$$T_{C(m)max} \leq T^*_{(m)dop} \quad (2)$$

where:

- $r_{C(A)max}$ - total, maximum, random horizontal displacement of the ship (more precisely - of the permanent point A associated with the ship) in relation to the maintained position (Fig.1)
- $r_{(A)dop}$ - permissible horizontal displacement of the ship in relation to the maintained position, the value of which depends mainly on the kind of work carried out on the ship in question
- $T_{C(m)max}$ - total, maximum random force in the wire „m" of the ship positioning system
- $T^*_{(m)dop}$ - permissible load of the wire „m" of the ship positioning system, which depends on the wire type and assumed calculation method (Safety coefficients related to accuracy of total wire load calculations are proposed in [1]).

Apart from the criteria (1) and (2) additional owners' requirements concerning service and design may be imposed, such as :

- the mooring system should permit self-anchoring and self-unanchoring of the ship
- the mooring system should be of as low weight and as small size as possible
- anchors should be located possibly close to the bow and stern shell plating
- electric power demand for the mooring system should be as low as possible
- the mooring positioning system has to comply with all classification society rules' requirements for the conventional anchoring system.

In the case of a new ship the additional requirements are quite easy to follow or they may be of minor importance. However, ensuring compliance with them at designing the mooring positioning system for an existing ship may be difficult and entail ship reconstruction. The presented design of the mooring positioning system has been worked out for the existing, small salvage ship. For such ship the system weight should be low and the equipment overall dimensions small, whereas electric power demand of the mooring system should not exceed the electric power reserve available from the ship power plant.

ENVIRONMENTAL CONDITIONS AND DESIGN PARAMETERS OF THE SYSTEM

The mooring positioning system of the salvage ship was designed so as to comply with the following requirements :

- the ship will be positioned by means of 4 anchors (Fig.1)
- the ship position is to be kept within water depth ranging from 10 to 100 m under the following maximum weather conditions :

wind

- average wind velocity (5° B) — 10.6 m/s
- range of wind direction variations relative to ship position — 0÷360°

waves

- significant wave height — 0.85 m
- characteristic wave period — 3.8 s
- range of wave direction changes relative to ship position — 0÷360°

It was assumed that under the above specified weather conditions :

★ the maximum deviation from the preset position, including motions, should not exceed the following values :
  - 2.0 m for water depth of 10 m
  - 4.2 m for water depth of 50 m
  - 6.0 m for water depth of 100 m

★ the maximum deviation from the actual ship course ± 10°.

Main design parameters of the mooring positioning system are as follows :

→ the diameter and breaking strength of mooring wire (d, F)
→ the length of mooring wire (L)
→ the pretension in mooring wire (T_w)
→ pulling force and capacity of mooring winch (P, N).

These parameters are decisive for compliance with the requirements of the mooring positioning system under the assumed environmental conditions.

ANALYSIS OF DESIGN REQUIREMENTS AND ENVIRONMENTAL CONDITIONS

The salvage ship is exposed to exciting forces due to wind and waves. The forces of quasistatic character push off the ship to the average position (Fig.1) and at the same time act dynamically causing high-frequency and low-frequency motions. The anchored ship displacements are associated with loads in particular wires of the mooring system.

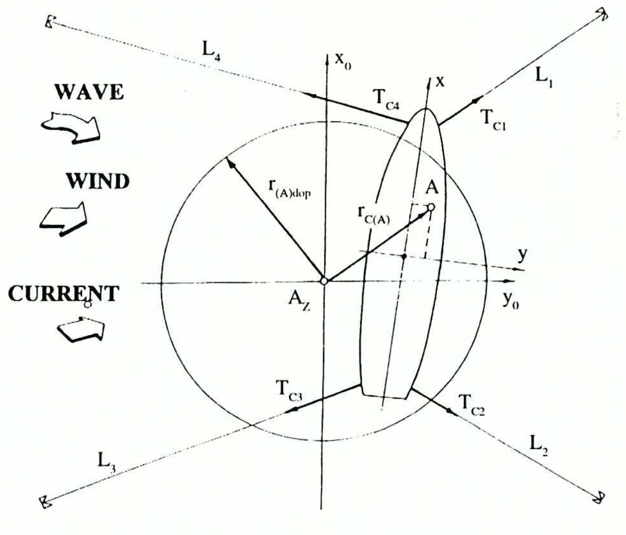

Fig.1. Ship positioning by means of the mooring system

Solution of the design task consists in :

- calculation of exciting forces due to wind and waves according to [2]
- calculation of the maximum ship displacements and maximum loads of the mooring system wires at the assumed parameters of the mooring system
- checking whether the design requirements are complied with.

The ship displacements during its positioning and thus loads of the mooring wires, are related to weather conditions and the mooring positioning system paramters. The most decisive are the following parameters :

➢ the mooring wire diameter d
➢ the mooring wire pretension T_w.

The wire length L necessary for positioning and anchoring operations depends also on those parameters. Maximum loads in wires and wire lengths affect also capacity of mooring winches and their pulling forces. Weight of the whole mooring positioning system, of great importance for the small salvage ship, is related to the parameters. Therefore in the preliminary project of the salvage ship positioning system the influence of the mooring wire diameter d and pretension T_w on accurate positioning and on weight of the whole mooring system was investigated so as to ensure compliance with all design requirements.

Influence of mooring wire diameter and pretension on ship positioning accuracy and system weight

In result of consideration of the character of exciting forces due to wind and waves general mathematical model of the anchored ship displacements was formulated in the form of the following equations :

✷ describing average, quasistatic ship position
✷ describing low-frequency (second order) motions
✷ describing high-frequency (first order) motions.

The equations and their solutions were presented in detail in [3]. The following respective results can be obtained :

✷ the quasistatic displacements relative to the average position $S^{(0)}_{(l)}$
✷ the high-frequency motions $S^{(1)}_{(l)}$
✷ the low-frequency motions $S^{(2)}_{(l)}$

where :

l - motion number, l = 1...6

The mooring wire load $T_{(m)}$ for the preset parameters: d, $T_{w(m)}$, L_m, and the water depth H depend on the ship displacements :

$$T_{(m)}\,[S_{(l)}(t)] \tag{3}$$

where:

m - wire number in the mooring positioning system, m = 1....n (Fig.1, n=4).
t - time

Thus at the displacements $S^{(0)}_{(l)}$, $S^{(1)}_{(l)}$, $S^{(2)}_{(l)}$ the average quasistatic load $T^{(0)}$ high-frequency load $T^{(1)}$ and low-frequency load $T^{(2)}$ are generated in the mooring wires, respectively. The maximum total displacements of the ship $r_{C(A)max}$ and maximum total loads of the mooring wires $T_{C(m)max}$ are mainly determined by the average quasistatic displacements $S^{(0)}_{(l)}$ and low-frequency motions $S^{(2)}_{(l)}$.

Results of numerical calculations

The numerical calculations were performed for the following values :

⇒ the mooring wire diameter d = 32, 36, 40, 44 mm
⇒ the pretension T_w = 50, 100, 150, 200 kN,

as the mooring wire diameter d and pretension T_w are decisive for the ship displacements and mooring wire loads at the preset weather conditions and water depth at which the ship is to be positioned.

Calculation results of the average quasistatic ship displacements $r^{(0)}$ and the wire loads $T^{(0)}$ at these displacements versus the mooring wire diameter d_c and pretension T_w, respectively, are illustrated in Fig.2

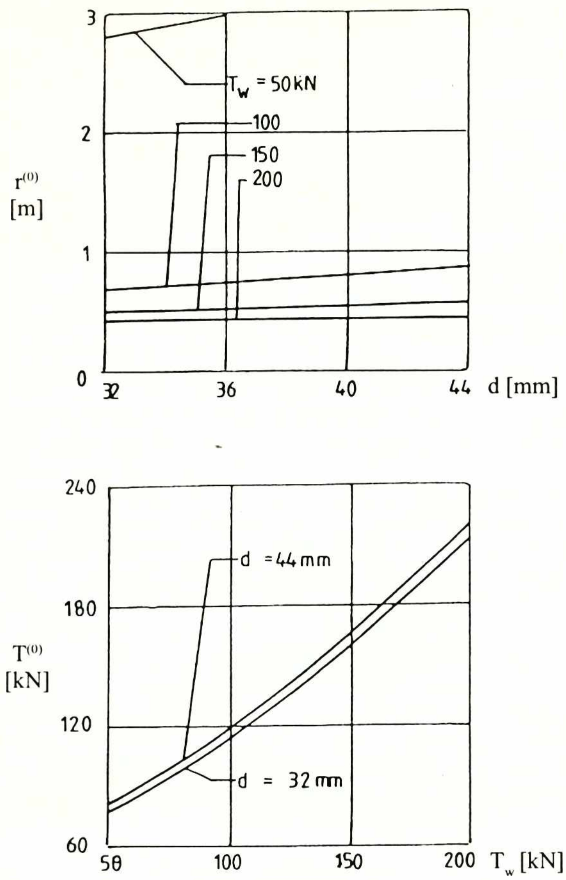

Fig.2. Influence of the pretension T_w and mooring wire diameter d on the average displacement $r^{(0)}$ and mooring wire load $T^{(0)}$ (water depth H=100 m, JONSWAP wave spectrum 5°B)

Increase of the pretension T_w causes reduction of the displacement $r^{(0)}$ but also it entails increase of the wire load $T^{(0)}$. Increase of the mooring wire diameter d results in increase of the displacement $r^{(0)}$ and the wire loads $T^{(0)}$.

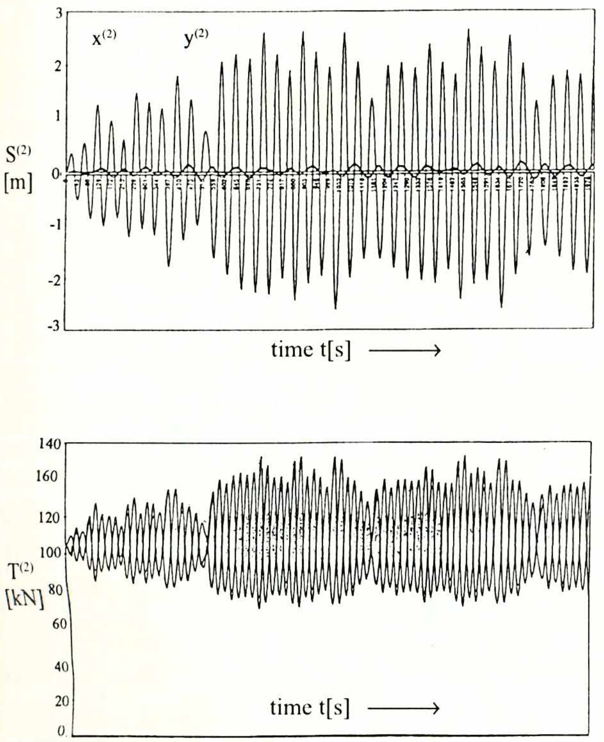

Fig.3. Simulated time records of slowly varying motions and wire loads at : water depth H = 100 m, d= 36 mm, T_w = 100 kN, wave angle β_w = 90°, JONSWAP wave spectrum5°B

Fig.3 shows results of exemplary simulation calculations of low-frequency motions of the anchored ship as well as of low-frequency loads of the mooring system wires related to the pretensions, according to [3]. For low-frequency motions, increase of the pretension T_w results in reduction of low-frequency motion amplitudes and in increase of amplitudes of low-frequency dynamic loads of the mooring system wires.

The total length of mooring wires L_c necessary during the ship positioning and anchoring operations were determined on the basis of those results. For the calculated values of the length L_c the total weight of 4 mooring wires was determined in dependence on the values of the wire diameter d and pretension T_w. Results of the calculations are presented in Fig.4.

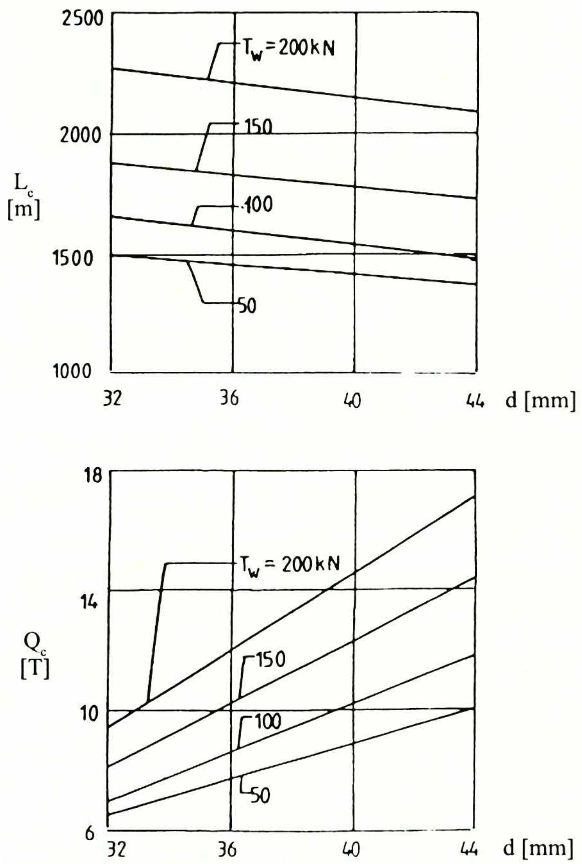

Fig.4. Influence of the pretension T_w and mooring wire diameter d on the length L_c and total weight Q_c of the mooring wires (water depth H=100 m, JONSWAP wave spectrum 5°B)

When the diameter and pretension values increase the necessary wire length values are reduced but the total weight increases. The thinner the wires the less their total weight. However, reduction of the wire diameters entails also reduction of the permissible load T_{dop} for the mooring wires.

Optimum parameters of the mooring positioning system of the salvage ship

Particular design parameters of the mooring positioning system have different influence on compliance with requirements imposed on the system.

Positioning accuracy

Wire diameter reduction or pretension increase results in reduction of the positioned ship displacements (Fig.2). The minimum diameter of mooring wire, however, should not be less than that required by the classification societies' rules for the conventional anchoring system. On the other hand, pretension increase makes observing other requirements difficult.

Weight and overall dimensions of the system components

The less the mooring wire diameter and the lower the pretension value the less total weight of all mooring wires (Fig.4). The anchors and mooring winches have lower weight and smaller overall dimensions at smaller mooring wire diameters and lower pretensions. The lower the mooring wire loads the smaller (lighter) the foundations and stiffenings of the hull at the places where the mooring system equipment is fixed.

Power demand

The lower pretension values of the mooring wires the less their load during the ship positioning. Pulling force and power output of the mooring winches are then lower. However, the power output of the mooring winches is determined mainly by mooring wire heaving-in / paying-out speed. The bigger this speed, the shorter the anchoring operation time (dropping of 4 anchors and paying-out of mooring wires) or unanchoring operation time.

In this situation determining the mooring positioning system parameters requires optimizing calculations.

The final values of the mooring system wire parameters are as follows :

- d = 32 mm
- L_c = 1500 m (the length suitable simultaneously for positioning, self-anchoring and self-unanchoring of the ship)
- T_w = 70 kN.

The capacity of one mooring winch is about 70 kW at these parameter values.

Other parameters of the mooring winch are of the following values :

- maximum pulling force at the middle wire layer 160 kN
- mooring wire heaving-in speed at the middle layer and the maximum pulling force 0÷15 m/min
- maximum mooring wire heaving-in speed at low pulling force 0÷200 m/min
- pulling force at the middle wire layer and maximum mooring wire heaving-in speed 40 kN.

DESIGN OF THE SYSTEM AND ITS INSTALLATION ON THE SHIP

The mooring positioning system of the ship in question, shown in Fig.5 and 6, consists of :

- 4 mooring winches (2 bow and 2 stern winches) with hydraulic drive made by RAPP HYDEMA A/S, Norway, and HYDRO NAVAL, Poland
- 2 hydraulic power packs (1 bow and 1 stern pack)
- 5 special anchors of high holding force (2 bow, 2 stern and 1 spare anchor)
- 5 mooring wires (2 installed on bow winches, 2 on stern winches and 1 spare wire)
- 4 fairleads and rollers for guiding the mooring wires
- 4 racks for fastening the anchors in en-route position
- computer control system.

The mooring positioning system was installed on the ship in question by the Naval Shipyard, Gdynia, in accordance with the project elaborated by the CONMAR, Poland [4,5]. The mooring positioning system installation required the existing mooring equipment to be removed and relevant ship hull areas modifed or strengthened.

Mooring winches

The system includes the mooring winches with hydraulic drive (each two winches are supplied from one hydraulic power pack).

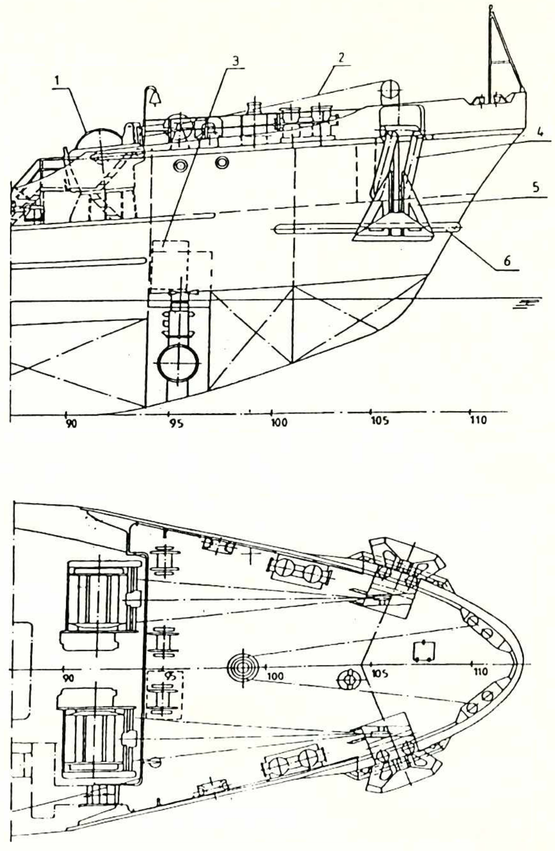

Fig.5. Mooring positioning system of the salvage ship – bow part 1- mooring winch, 2- mooring wire, 3- hydraulic power pack, 4- fairleads and rollers, 5- anchor, 6- anchor rack

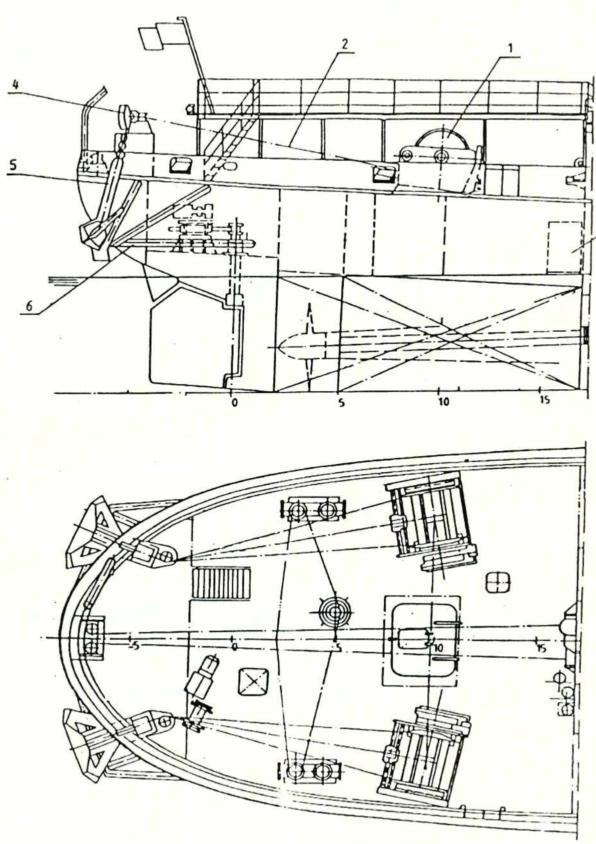

Fig.6. Mooring positioning system of the salvage ship – stern part 1- mooring winch, 2- mooring wire, 3- hydraulic power pack, 4- fairleads and rollers, 5- anchor, 6- anchor rack

Each mooring winch is equipped with :

★ the system for smooth control of drum rotations in low-speed range at nominal pulling force
★ the system for smooth control of drum rotation in high-speed range at the pulling force up to 20% of its nominal value
★ the sensors for measuring the drum rotations and the paid-out mooring wire length
★ two independent systems of sensors for measuring the mooring wire load.

Bow mooring winches are additionally equipped with hydraulic accumulators to make it possible to drop the bow anchors in the case of ship power plant failure.

Control of the mooring winches is arranged in three ways :

➢ manual control from local control stands at the mooring winches (this control mode can be effected also in the case of computer system failure)
➢ remote, hand-operated control from ship wheelhouse console (hand-operated control of individual winches, or integrated simultaneous control of all mooring winches by means of a joystick)
➢ remote automatic control of mooring winches by means of the computer system.

Anchors

Special, Flipper Delta 2000 kg anchors of high holding force are used for ship positioning. The anchors are joined to the mooring wires by means of shackle swivel and socket connections. In en-route position the anchors are fastened to the pipe racks welded to the shell plating as well as by means of chain stoppers.

Computer control of the mooring positioning system

The computer control system designed and built in compliance with the requirements for dynamic positioning systems, is used to :

- remotely control (manually or automatically) the mooring winches during ship anchoring / unanchoring and ship positioning operations
- remotely control (manually or automatically) the ship propellers (of the main propulsion system and thrusters) during ship anchoring / unanchoring operations.

The software installed in the computer system, elaborated on the basis of the algorithms published in [6], makes it possible to determine the positions where the four anchors have been dropped in a specified order. The computer system is used also for :

❖ converting the measurement signals from the sensors fitted on the mooring winch into length and load values of particular mooring wires
❖ calculating the wind effect forces acting on the ship
❖ calculating the ship position.

All the data are recorded and graphically displayed on monitors. Also sensors for measuring the wind direction and velocity as well as ship position and ship movement parameters are also connected to the computer system.

THE MOORING POSITIONING SYSTEM OPERATION UNDER BASIC SERVICE CONDITIONS

The basic service conditions of the ship mooring positioning system are as follows :

- conventional anchoring
- anchoring and unanchoring (for ship positioning)
- ship displacement after anchoring
- ship positioning.

Conventional anchoring The ship positioning system complies with requirements of classification rules for the conventional anchoring. Both bow and stern anchors can be dropped. The mooring winches can be manually controlled, locally or remotely by means of the ship wheelhouse console. Only bow mooring winches are designed for dropping the anchors in the case of total failure of ship power plant.

Ship anchoring and unanchoring before and after the ship positioning operation can be performed remotely: manually or automatically. Depending on water depth, weather conditions and kind of work carried out, the computer program calculates co-ordinates of the points where four anchors have been dropped. The system operator manoeuvres the ship in such a way (by using ship propellers) as to have the anchors dropped in a specified order, have the mooring wires heaved-out and ensure that the ship occupies the preset position. All the operations can be performed also automatically – then the computer program controls the ship and the mooring winches under the operator's supervision. Possibly short time of ship anchoring is thus obtained. Hoisting the anchors is carried out in the reverse order (either in manual or automatic operation mode).

Ship displacement can be effected if after ship anchoring the preset (maintained) position has been changed. The ship can be displaced to a limited distance by heaving-in / paying-out the mooring wires, depending on water depth, weather conditions and lengths of paid-out mooring wires. The maximum, permissible ship displacements are calculated by the computer system. The mooring winches during ship displacement can be controlled manually by using the joystick (integrated control) or automatically by means of the computer system.

Ship positioning starts after its anchoring (all anchors dropped), assuming the preset (maintained) position and producing calculated pretensions in the mooring wires. The pretensions are produced by heaving-in the calculated lengths of particular mooring wires (manually or automatically). After the pretensions preset for given weather conditions are produced the mooring winches are braked and the mooring positioning system changes over to passive ship positioning. Under more severe weather conditions the computer system modifies values of pretensions in particular mooring wires, so as not to exceed permissible deviations from the preset position. Then the mooring positioning system acts to keep the ship position. Measurements of the length of paid-out mooring wires (so as to prevent paying-out the whole mooring wire from the winch), as well as measurements of the mooring wire loads (in order to prevent breaking of the mooring wires) are constantly performed during the ship positioning operation. All the data, including possible warnings and alarms, are displayed on control consoles and monitors.

SEA TESTS OF THE MOORING POSITIONING SYSTEM

Tests and trials of the ship with the mooring positioning system were carried out in the end of 1997 and in 1998 .The tests were intended for :

⇒ checking of the system equipment parameters (e.g. pulling forces of mooring winches, anchor holding forces)
⇒ checking of correctness of anchor dropping, hoisting and fastening
⇒ testing of the manual and automatic control systems
⇒ checking of positioning accuracy
⇒ training of the system operators
⇒ checking of the algorithms describing the ship dynamics.

The tests were performed in the Baltic under different weather conditions and at different water depths. During the tests some modifications were introduced to the software and some design modifications made to improve carrying the mooring wires and fastening the anchors. During the ship anchoring, the anchor fastening and ship manoeuvring operations were performed at first by using manual control, then autocontrol system. The ship was controlled by the computer system which selected the optimum manoeuvres between particular positions at which the anchors were to be dropped. This made it possible to shorten duration of dropping the four anchors and of the entire ship anchoring operation 4÷5 - fold. The operations were performed also at night with no lighting.

CONCLUDING REMARKS

- The presented mooring positioning system of the ship is the first such system designed and built in Poland.
- The system design was adapted to the existing ship. Its compliance with all design assumptions and requirements was demonstrated during the tests and trials at sea.
- On the basis of the experience gained from the tests and trials, a new design of the mooring positioning system of improved service parameters was prepared for second salvage ship.

NOMENCLATURE

A_z - assumed ship position (point)
G - centre of gravity of the ship
L_c - total length of mooring wires
L_m - length of m-th mooring wire
$r^{(0)}$ - average quasistatic displacement of the ship
$S_{(i)}^{(0)}$ - quasistatic displacement of motions
$S_{(i)}^{(1)}$, $S_{(i)}^{(2)}$ - displacements of first and second order motions, respectively
$T^{(0)}$ - average quasistatic load of the mooring wire
$T_{C(m)}$ - total load of m-th mooring wire
$T_{(m)}$ - load of m-th mooring wire
$T_{(m)}^{(0)}$ - quasistatic load of m-th mooring wire
$T_{(m)}^{(1)}$ - dynamic load of m-th mooring wire due to the first order motions
$T_{(m)}^{(2)}$ - dynamic load of m-th mooring wire due to the second order motions
$T_{w(m)}$ - pretension in m-th mooring wire

BIBLIOGRAPHY

1. Fumholt E.: „Mooring systems for offshore operations". Norwegian Maritime Research, 1975, No.4
2. Szelangiewicz T.: „Analysis of Power Demand for Dynamic Positioning System of Salvage Ship". Second International Shipbuilding Conference - ISC '98. St. Petersburg, November 1998
3. Szelangiewicz T.: „A simulation model for a mooring positioning system of a vessel in presence of wind, current and waves". Polish Maritime Research, 1996, No 2(8), Vol.3
4. Szelangiewicz T.: „Preliminary Design of 570 Type Salvage Ship Positioning System" (in Polish). CONMAR Research and Technology Office. Szczecin, 1996
5. Szelangiewicz T.: „Final Design of 570 Type Salvage Ship Positioning System Installation" (in Polish). CONMAR Research and Technology Office. Szczecin, 1997
6. Szelangiewicz T.: „Mathematical model of salvage ship with positioning systems" (in Polish). CONMAR Research and Technology Office. Szczecin, 1997

Conference

1998 Conference of the International Congress of Maritime Museums (ICMM)

The Central Maritime Museum in Gdańsk has been a member of the ICMM since 1982. It was entrusted with organizing the '98 Conference of the Congress. The conference was held in Gdańsk on 26 to 28 August with more than 80 persons attending, inclusive of over 60 or so from abroad which represented maritime museums of Denmark, Estonia, Finland, France, Spain, Netherlands, Malta, Germany, Norway, Russia, Slovenia, Sweden, Ukraine as well as USA, Australia and Bermuda. Dr Kevin Fewster from Sydney, the President of ICMM, was also present in Gdańsk.

20 conference papers were submitted, most of which dealt with the historic ships.

Session I was devoted to Polish museums which were presented by :

- Mr J.Litwin of the Central Maritime Museum, Gdańsk
- Messrs. S.Kudela and Z.Wojciechowski of the Polish Navy Museum, Gdynia
- Mr K.Siudziński of the Oceanographic Museum and Marine Aquarium, Gdynia
- Messrs. M.Sawala and A.Szymczak of the maritime museums of the Szczecin District.

During **Session II** the East-European maritime museums were presented, namely :

- the Global Ocean Museum in Kaliningrad, by Mr V.Stryuk
- the Maritime Museum in Tallin, by Mr U.Dresen
- the „Sergei Masera" Maritime Museum in Pirane (Slovenia), by Mr F.Bonin
- Schiffahrtsmuseum in Rostock, by Mr P.Danker-Carstensen.

The leading topics of **Session III** were :

- „New trends in conservation and presentation of ship and boat wrecks"
- „Waterborne or in a dry dock ? How to preserve historic ships in museums ?"

Particular achievements in the field of conservation and preservation of the historic ships, bringing them to former beauty as well as making them available to visitors were presented by :

- Mr P.De Orsay of the Independence Seaport Museum, Philadelphia (the cruiser OLYMPIA of 1892)
- Mr C.P.Huurman of „Prins Hendrik" Museum in Rotterdam (the ship DE BUFFEL of the 2nd half of XIX century)
- Mr U.S.Kallberg of the Maritime Museum in Turku (the sailing ship SUOMEN JOUTSEN).

Moreover, Mr H.J.A.Dessens of the Maritime Museum in Amsterdam considered a general theme on „Ethics and practice in conservation and presentation of ships".

The last, **4th session** dealt with enlivening the older museums, i.e. introducing them into XX and XXI century. Contributions to the topic were as follows :

- Mrs D.Jessop of the Southaustralian Maritime Museum in Adelaide presented education proposals in the area of informing technique and interactive exhibitions
- Mr A.E.Rodriguez described transformation work of a former military bakery at Vittoriosa into the Maritime Museum of Malta
- Mr F.Bellec presented a French experience : the Oceanographic Museum of Monaco and Maritime Museum at La Rochelle
- Mr W.Bijleveld talked over attempts leading to general renovation of the Maritime Museum in Amsterdam
- Mr F.Rieck acquainted the participants with the work on construction of a new port for the Viking Boat Museum at Roskilde.

It is in the conference hall of the new headquarters of the Central Maritime Museum located in the renewed granary „Dąbrowa", a historic building of Gdańsk port on the riverside of Motława, that the '98 Conference took place.

Within the conference program its partcipants had an opportunity to visit the Polish Navy Museum and the BŁYSKAWICA, destroyer converted to museum, Oceanographic Museum and Marine Aquarium of the Sea Fishery Research Institute, the DAR POMORZA, training tall ship converted to museum, all located in Gdynia, and the Fishery Museum, lighthouse and seal breeding aquarium at Hel.

The organizers also provided for visiting exhibitions of the Central Maritime Museum, as well as observing the ship models taking part in IX World Championship of C-class Ship Models held in Gdańsk.

The conference proceedings will be published in the next Annual Report of the Central Maritime Museum, Gdańsk.