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An approach to optimization of ship design parameters with accounting for seakeeping ability

SUMMARY

In the paper a method, using a genetic algorithm, of searching optimum ship design parameters which satisfy economical and technical criteria with accounting for seakeeping ability, was presented. To assess seakeeping ability of a ship in waves the ship operational effectiveness factor E was applied. An example of application of the approach is attached and discussed.

AN OPTIMIZATION METHOD OF SHIP DESIGN PARAMETERS

Introduction

In the ship design process the task of the ship designer is to find an optimum solution which would fulfil shipowner's specification and simultaneously – in regard to the angaged shipyard – would lead to as-low-as-possible cost of building of the designed ship. The optimum design solution is usually searched for two basic aspects : economical and technical. The best economical solution is the ship which can fulfil her function at a minimum outlay (sum of building and operational costs). The technical conditions deal with the ability of the ship to fulfil her function, which – in the case of transport ship – – amounts to her floating in the state which makes it possible to carry cargo safely in real environmental conditions (represented mainly by wind and waves).

The technical conditions consist of different criteria established mainly by the classification societies or institutions angaged in ship safety at sea (such as IMO), and dealing with ship floatability, stability, unsinkability, freeboard etc. The criteria are not directly related to real weather conditions in which a ship is operated. The weather conditions greatly influence ship safety at sea. Therefore it is often and often demanded to provide the ship with good seakeeping ability.

In the preliminary design stage multicriterial optimization of ship design parameters is more and more frequently applied [6],[7]. Among the design criteria those for seakeeping performance of the ship in waves can also be found. To obtain effective models for the multi-criterial assessment of ship design solutions the appropriate conditions and criteria should be described by possibly simple relationships comprising basic ship design parameters [7]. An example of such functions approximating the amplitude characteristics of ship motions in waves and accompanying phenomena, obtained by applying artificial neural networks, was presented in [9] and [10]. As the seakeeping ability covers many effects of ship - wave interaction such as : rolling, pitching, accelerations, deck wetness and propeller emergence, slamming, it is advisable to use – in optimizing analyses – a factor by which it would be possible to comprehensively assess a ship design from the point of view of seakeeping ability. To this end application of *the ship operational effectiveness factor* is most useful [8], which generally determines possibility of safe fulfilling by a ship her transport mission at assumed speed and course over given sea regions in which different weather conditions may occur.

In the multicriterial optimization an optimum solution is searched against assumed criteria which can be conflicting to each other. Therefore influence factors are assigned to each of them by the designer or shipowner, often subjectively. This make it possible to establish appropriate proportions between values of individual partial criteria. Searching for an optimum solution within an assumed domain of constraints is equivalent to searching the best solution within a domain of compromise. Optimum compromise solutions are characterized by a lack of superiority of one solution over the other in respect to all partial criteria.

From the domain of compromise solutions the ship designer or owner is able to choose an optimum solution accepted by him on the basis of his own (subjective) criteria.

The multicriterial optimization method presented in [6] does not include any seakeeping ability criterion. Therefore in this work, as the economical criteria are often considered decisive for the shipowner, it was decided to split the process of searching for optimum ship design parameters with accounting for seakeeping ability into two phases :

- **In the first phase** the multicriterial optimization of design parameters is carried out against assumed general ship design criteria (technical and economical) and by basing the optimizing mechanism on the genetic algorithms. As a result of the performed optimization the set of compromise solutions, Ω, is obtained which satisfies the most important design criteria.
- **In the second phase** the set Ω is verified from the point of view of optimum seakeeping ability of a designed ship, i.e. such solution is searched for which a parameter characterizing seakeeping ability of the ship reaches its maximum value, and the remaining ship qualities and economical features would not appear worser. To assess ship seakeeping ability the ship operational effectiveness factor E calculated with the use of the ship motion model obtained by means of artificial neural networks, is applied.

The ship operational effectiveness factor

Merchant ships sailing on given shipping routes are usually exposed to action of waves (on the most frequented routes only several halcyon days per year occur [1],[2]). The direct effect of the wave action are ship's oscillation motions and their derivatives : velocities and accellerations. The secondary phenomena accompanying the oscillation motions are :

deck wetness, propeller emergence, slamming, worsening of ship stability and manoeuvrability, additional dynamic loads on ship hull.

Most of the phenomena is hazardous for the ship hence they should be taken into account already in the preliminary stage of ship design. However applying each of them separately as design criteria in optimization procedures, would be rather troublesome even if they had a form of simple functions describing the phenomena. Therefore it seems purposeful to use only one factor which would comprise all phenomena most dangerous for the ship. To this end the ship operational effectiveness factor can be used [4],[8].

The ship effectiveness factor E is defined as ship's ability to safely fulfil her shipping mission during a voyage with a given speed and course over sea regions through which her shipping route goes and where different weather conditions may occur.

$$E = \sum_R \sum_S \sum_\mu \sum_{hT} \sum_V \sum_\psi [P(\Gamma_i = 1)] \qquad (1)$$

$$i = 1,2,...D$$

where :

- D – number of dangerous wave-induced phenomena taken into account in calculation of E factor
- $P(\Gamma_i = 1)$ – probability that *i-th* phenomenon value will not exceed a permissible value for given weather conditions and ship motion parameters.

Indices at symbols Σ :

- R – sea region through which a given shipping route goes
- S – season of the year
- μ – geographical direction angle of wave
- h,T – wave statistical parameters : its height and period, respectively
- V – ship speed
- ψ – geographical course angle of ship.

Values of the particular wave-induced phenomena are calculated on the basis of the frequency characteristics of ship oscillation motions [4],[8] for the wave parameters (h, T, μ) and ship sailing parameters (V, ψ). If the calculated value of a given phenomenon is smaller than that of the assumed criterion [3] then the function $\Gamma = 1$; this means that there is no hazard for the ship from the side of the phenomenon in question. As different parameters distinguished by the indices R, S, μ, h, T, ψ are attributed to the shipping route therefore probability of their simultaneous occurence is equal to :

$$P = f_R \cdot f_S \cdot f_\mu \cdot f_{hT} \cdot f_V \cdot f_\psi \qquad (2)$$

where :

- f_R – occurence probability that a given ship may sail in the sea region R
- f_S – occurence probability that a given ship may sail in the sea region R during the season of the year, S
- f_μ – probability that the waving from the angular direction μ may occur in the sea region R during the season of the year, S
- $f_{h,T}$ – probability that the waves of the parameters h, T may occur from the angular direction μ
- f_V, f_ψ – occurence probability that a given ship may sail in given conditions with the speed V and course angle ψ.

E factor value can be obtained with the use of (1) by calculating function Γ_i for every probability P and by realizing summation – over all indicated parameters – of only those probabilities for which $\Gamma_i = 1$. The result is a number from the interval [0,1], and the greater its value the more suitable the considered ship design for a given shipping route, i.e. the more safely she could operate on this route.

The multicriterial optimization method with application of genetic algorithms

In the multicriterial optimization, for a given vector of constant input quantities, {C} :

$$\{C\} = \{C_1, C_2, ... C_m\} \qquad (3)$$

a vector of decision variables, {X}, is searched for :

$$\{X\} = \{X_1, X_2, ... X_n\} \qquad (4)$$

for which a vector of criteria, {K(X)}, :

$$\{K(X)\} = \{K_1(X_1), K_2(X_2), ..., K_n(X_n)\} \qquad (5)$$

would satisfy requirements for a scalar objective function F(X) :

$$F(X) = \sum_{i=1}^{n} a_i k_i \Rightarrow \max \qquad (6)$$

where :

- a_i – weighting factors for the partial criteria K_i
- k_i – standardizing functions for the partial criteria K_i
- C_i (i = 1,2,..., m) – constant input quantities e.g.: ship speed, operation range, cargo capacity, maximum draught
- X_i (i = 1,2,..., n) – independent decision variables e.g.: ship length, breadth, hull form coefficients, ratios of ship main dimensions.

In the multicriterial optimization some constraints are imposed on the decision variables :

$$X_{i\,min} \le X_i \le X_{i\,max} \qquad (7)$$

Hence as a result the n-dimensional space is obtained in which the design solutions satisfying the assumed criteria K_i for the variables X_i fulfilling the assumed constraints, are contained.

By introducing the additional dependent variables {Y} (e.g. ship displacement, engine output, mass of empty ship) :

$$\{Y\} = \{Y_i(X_i)\} \qquad (8)$$

$$i = 1,2,..., r$$

together with their own constraints :

$$Y_{i\,min} \le Y_i \le Y_{i\,max} \qquad (9)$$

the space of optimum design solutions can be made smaller.

For the multicriterial optimization different methods and algorithms are applied [5], [6], [7]. Nowadays greater and greater interest is paid to random methods, more universal than analytical ones, as they do not introduce any special requirements for the objective functions. The methods based on genetic algorithms belong to that class.

The genetic algorithms elaborated in 1970ths have found many applications to optimization and control models. Such models are characterized of high effectiveness. In the method based on genetic algorithms natural selection strategy is used (*per analogiam* to evolution of living organisms where genetic changes consist in „crossings" and „mutations" of genetic material). The optimization methods based on genetic algorithms operate in the similar way. In the methods the coded set of input values of the decision variables X_i is selected (commonly in a binary form). The so-obtained binary set corresponds with the initial chromosome of a given individual. During the optimization process the set is subject to random operations of „crossing" and „mutation" during which some parts of the binary set are changed. The obtained successive sets are subject to a selection process in order to eliminate solutions which do not satisfy the assumed criteria $K_i(X_i)$. The selecting operations are performed as long as such set of solutions (individuals) is obtained for which the objective function F(X) reaches its maximum. The algorithm and the computer software OPTISHIP applied in this work is described in detail in [5] and [7].

CHOICE OF OPTIMUM SHIP DESIGN PARAMETERS WITH ACCOUNTING FOR SEAKEEPING ABILITY – An example of application –

The first phase

For optimization of ship design parameters the OPTISHIP computer software based on a genetic algorithm was applied [5]. To exemplify this phase of optimization the following input data to the OPTISHIP software were assumed :

Ship's main technical data :

- type : container carrier
- range of deadweight : 30000÷32000 t
- range of container capacity : 2150÷2250 TEU
- ship speed : 20 knots
- operation range : 8000 Nautical miles
- specific fuel oil consumption : 180 g/kWh

Design constraints :

- ✓ maximum ship's breath : B_{max} = 41.60 m
- ✓ maximum ship's draught : d_{max} = 13.10 m
- ✓ minimum metacentric height : GM_{min} = 0.40 m
- ✓ minimum roll period : T_{min} = 12.0 s

Economical data :

- unit cost of hull steel : 400.00 $/t
- technological margin coefficient for steel hull : 1.05
- unit cost of hull outfit : 1020.00 $/t
- unit cost of engine room outfit (including main engine) : 2000 00 $/t
- unit cost of hull building : 10.50 $/h
- unit cost of outfitting (including E.R.) : 9.00 $/h
- unit labour consumption for outfitting (including E.R.) : 50.00 h/t
- shipyard's overhead cost factor : 34.00 %
- credit repayment costs : 950 000 $
- profit factor : 1.1

The above specified economical data serve only for comparisons as they vary with time and may appear not valid in another situation.

The design optimization was performed from the point of view of ship deadweight and propulsion power, and to this end the equal weighting factors were assigned to the two parameters, namely : 0.5 for deadweight and 0.5 for propulsion power, which appear in the objective function (6).

The obtained solutions were verified from the point of view of the most favourable values of the economical parameters and a set of 46 compromise solutions which fulfilled both technical and economical criteria, was selected. The set is presented in Tab.1.

Tab.1. *Set of optimum design solutions obtained by means of OPTISHIP software*

Solution number	L [m]	B [m]	d [m]	H [m]	C_B [–]
1	203.00	27.07	10.72	14.69	0.650
2	198.83	26.51	11.18	15.32	0.652
3	198.83	26.51	11.18	15.32	0.653
4	198.83	26.51	11.09	15.19	0.658
5	198.83	26.51	11.18	15.32	0.658
6	198.83	26.51	11.18	15.32	0.659
7	198.83	26.51	11.18	15.32	0.661
8	198.83	26.51	11.00	15.07	0.672
9	198.83	26.51	11.18	15.32	0.663
10	198.83	26.51	11.18	15.32	0.664
11	198.83	26.51	10.75	14.73	0.688
12	198.83	26.51	11.18	15.32	0.664
13	198.83	26.51	11.18	15.32	0.668
14	198.83	26.51	11.18	15.32	0.671
15	198.83	26.51	11.18	15.32	0.672
16	198.83	26.51	11.18	15.32	0.670
17	198.83	26.51	11.00	15.07	0.664
18	198.83	26.51	11.18	15.32	0.671
19	198.83	26.51	11.18	15.32	0.672
20	198.83	26.51	10.83	14.84	0.690
21	198.83	26.51	11.18	15.32	0.672
22	198.83	26.51	10.92	14.96	0.671
23	198.83	26.59	10.95	15.00	0.666
24	198.83	26.51	11.18	15.32	0.664
25	198.83	26.51	11.00	15.07	0.688
26	198.83	26.51	10.67	14.62	0.691
27	194.66	26.63	11.23	15.39	0.658
28	198.83	26.51	10.50	14.39	0.716
29	198.83	26.51	10.83	14.84	0.702
30	200.91	26.87	10.19	13.96	0.704
31	194.66	26.37	11.49	15.74	0.666
32	200.91	26.87	10.49	14.37	0.710
33	194.66	26.63	11.23	15.39	0.666
34	194.66	26.63	11.05	15.14	0.667
35	194.66	26.46	11.34	15.54	0.674
36	194.66	26.54	11.56	15.84	0.666
37	194.66	26.54	10.60	14.52	0.712
38	194.66	26.72	11.00	15.07	0.686
39	196.74	27.00	10.54	14.44	0.710
40	194.66	27.25	10.88	14.91	0.679
41	196.74	27.45	10.41	14.26	0.711
42	186.31	27.17	11.84	16.22	0.658
43	186.31	27.46	10.96	15.02	0.712
44	182.14	29.20	10.32	14.14	0.713
45	173.80	28.85	12.17	16.67	0.651
46	173.80	28.97	12.02	16.47	0.657

L, B, d, H, C_B - main design parameters of the ship : length between perpendiculars, breadth, draught, depth, block coefficient, respectively

The second phase

All the compromise design solutions obtained from the multicriterial optimization (1st phase) satisfy the general design criteria (technical and economical), but their seakeeping qualities are not known so far. In the second phase the optimization is carried out with the respect to seakeeping ability under the following assumptions :

★ the optimization is carried out for the following seakeeping qualities : rolling, heaving, pitching, slamming, bow deck wetness, propeller emergence, vertical acceleration at the bridge, vertical acceleration at the bow

★ the transfer functions of the considered ship oscillation motions, i.e. rolling, heaving, and pitching, are determined with the use of the method based on the artificial neural networks [9],[10]

★ the transfer functions of the considered phenomena resulting from the wave-induced ship motions, i.e. slamming, deck wetness, propeller emergence, vertical acceleration at the bridge and vertical acceleration at the bow are determined on the basis of values of the considered ship oscillation motions at the assumed points of the ship (Fig.1)

★ values of the particular oscillation motions and of parameters of the accompanying phenomena are determined on the basis of a short-term ship motion prognosis

★ shipping route : the Atlantic Ocean

★ design criteria for ship seakeeping qualities assumed in compliance with [3] are the following :

- roll angle (mean value) : 6 deg
- pitch angle (mean value) : 2 deg
- heave displacement (mean value) : 1.25 m
- slamming (max. probability of occurence) : 0.02
- bow deck wetness (max. probability of occurence) : 0.05
- propeller emergence (max. probability of occurence) : 0.25
- vertical acceleration at the bow (max. combined value) : 0.275 g
- vertical acceleration at the bridge (max. combined value) : 0.15 g

★ assessment of ship seakeeping ability is performed by applying the ship operation effectiveness factor E calculated separately for each of the assumed seakeeping quality as well as for all the qualities together on assumption of the following values of ship sailing parameters :

- the ship speed V : in the range from 0 to 20 kn, taken with 4 kn step
- the ship course angle $\psi = 0$
- the wave direction angle relative to the ship, β : in the range from 0 to 360 deg, taken with 30 deg step.

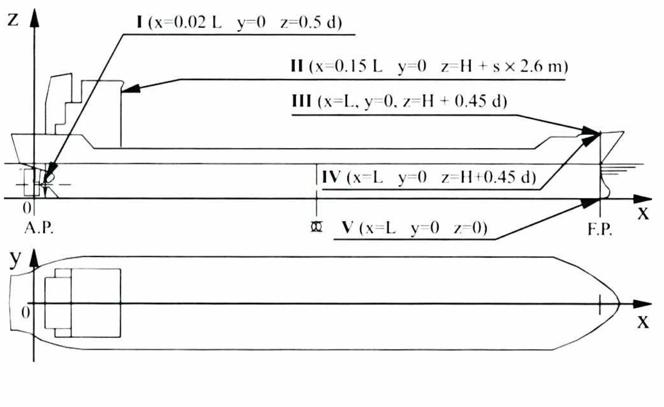


Fig.1. Coordinates of the points for which values of the selected seakeeping qualities were calculated : I – for propeller emergence ; II – for vertical acceleration at the bridge; III – for vertical acceleration at the bow; IV – for bow deck wetness; V – for slamming; s – number of superstructure tiers

Final results of the optimization of ship design parameters

The set of 46 solutions satisfying the assumed technical (i.e. ship propulsion power and cargo carrying capacity) and economical criteria was obtained as the result of the performed multicriterial optimization. The considered design parameters of the solutions are contained within the following ranges (which form the domain of the compromise solutions for the first phase of the optimization procedure, Fig.2) :

$$L = 173.8 \div 203.0 \text{ m}$$
$$B = 26.37 \div 29.20 \text{ m}$$
$$d = 10.19 \div 12.17 \text{ m}$$
$$H = 13.96 \div 16.67 \text{ m}$$
$$C_B = 0.650 \div 0.716$$

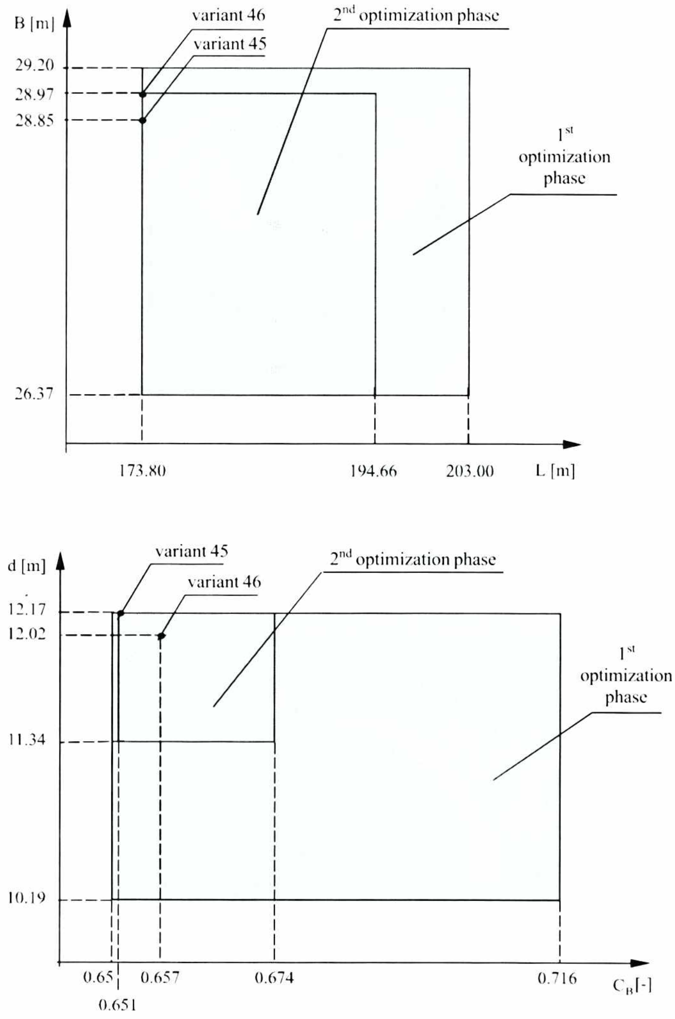
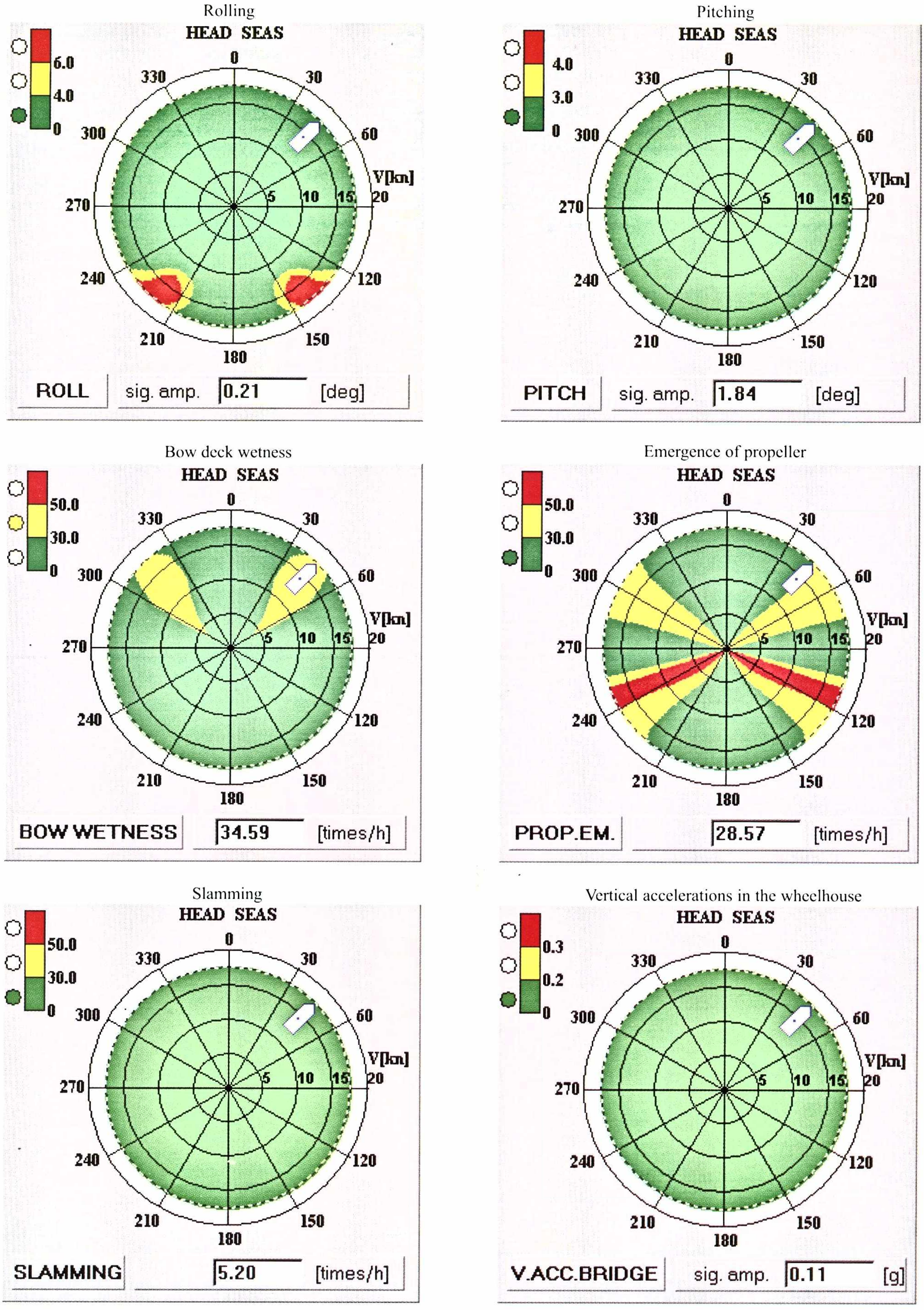


Fig.2. B-L and d-C_B parameter domains for the compromise design solutions obtained in the first and second phase of optimization process of the ship design parameters, and the points representing the finally selected optimum design variants (45th and 46th).

Next, values of the ship operation effectiveness factor E were calculated for the selected seakeeping qualities at the assumed equal values of their weighting factors in the collective form of the factor E.

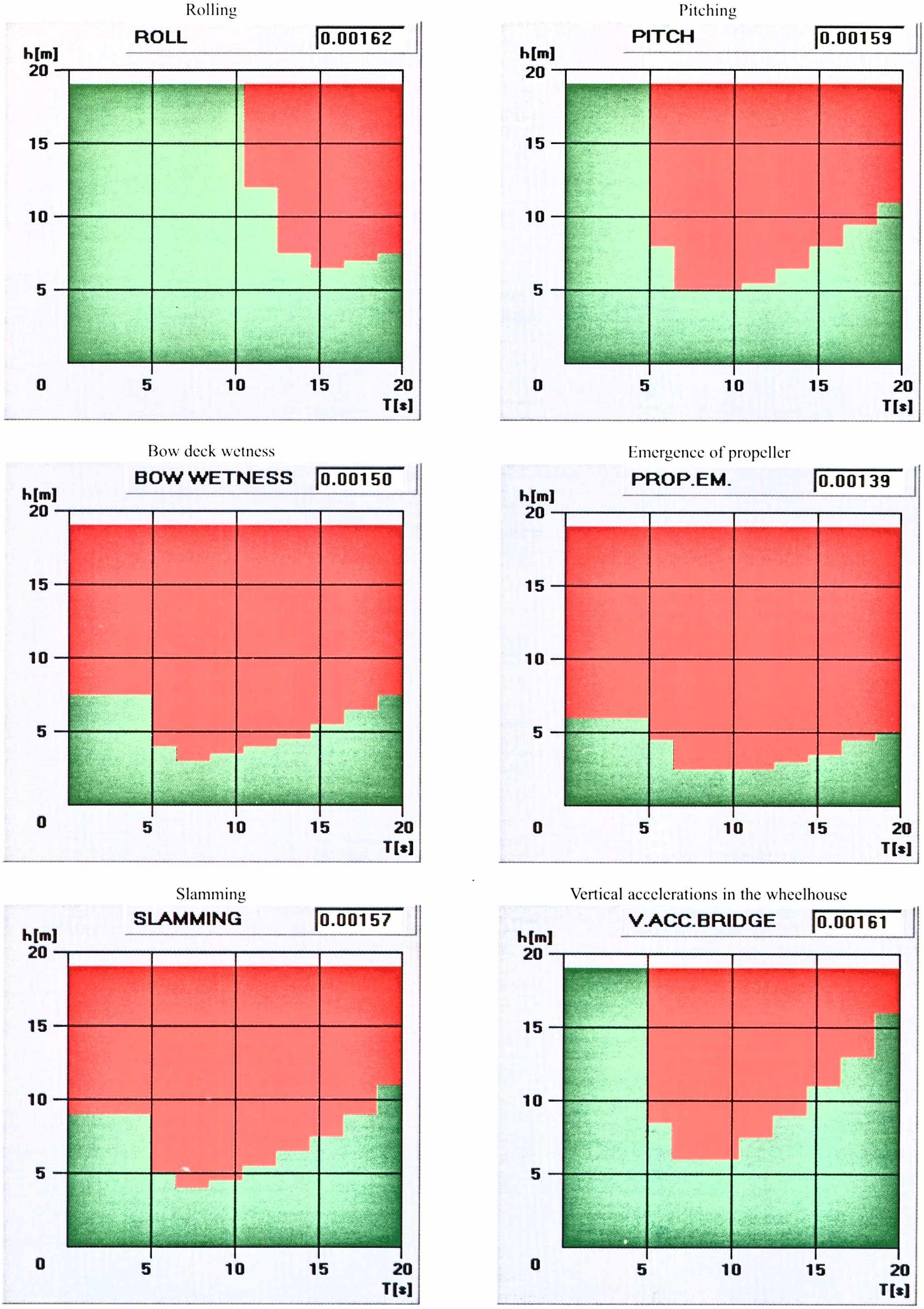
Influence of the ship speed V and course angle ψ of the considered containership on her seakeeping ability on the wave of the parameters h, T, are presented in Fig.3, and in Fig.4 Γ function values are exemplified.



■ – the ship sails safely, the appropriate criterion is not exceeded ■ – negligible hazard for the ship ■ – a considerable hazard for the ship

h = 3.25 m T = 8 s V = 14.2 kn $\psi = 45^0$

Fig.3. *Values of selected seakeeping abilities (qualities) of the containership on the wave of the parameters h, T*



– Γ = 1 (the criterion for seakeeping ability is not exceeded) – Γ = 0 (the criterion for seakeeping ability is exceeded)

Water area no.1. Season of the year : all seasons $\mu = 120^0$ $V = 14.2$ kn $\psi = 90^0$

Fig.4. *Values of probability P for function Γ = 1, calculated for selected seakeeping abilities (qualities) of containership*

Tab.2. Values of the ship operation effectiveness factor E calculated for 46 compromise solution variants (resulting from the first phase of the optimization process)

Variant number	All seakeeping qualities	Rolling	Pitching	Heaving	Vertical acceleration at bow	Vertical acceleration at bridge	Slamming	Propeller emergence	Bow deck wetness
1	0.86	0.99	0.99	0.94	0.99	0.99	0.95	0.91	0.89
2	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
3	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
4	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.91	0.89
5	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
6	0.69	0.74	0.98	0.94	0.99	0.99	0.95	0.92	0.90
7	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
8	0.87	0.99	0.99	0.94	0.99	0.99	0.95	0.91	0.90
9	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
10	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
11	0.87	0.99	0.99	0.95	0.99	0.99	0.95	0.91	0.89
12	0.78	0.85	0.98	0.94	0.99	0.99	0.95	0.92	0.90
13	0.71	0.77	0.98	0.94	0.99	0.99	0.95	0.92	0.90
14	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
15	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
16	0.78	0.85	0.98	0.94	0.99	0.99	0.95	0.92	0.90
17	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.91	0.89
18	0.71	0.77	0.98	0.94	0.99	0.99	0.95	0.92	0.90
19	0.78	0.85	0.98	0.94	0.99	0.99	0.95	0.92	0.90
20	0.87	0.99	0.99	0.95	0.99	0.99	0.95	0.91	0.90
21	0.69	0.75	0.98	0.94	0.99	0.99	0.95	0.92	0.90
22	0.87	0.99	0.99	0.94	0.99	0.99	0.95	0.91	0.89
23	0.87	0.99	0.99	0.94	0.99	0.99	0.95	0.91	0.89

Variant no.	All seakeeping qualities	Rolling	Pitching	Heaving	Vertical acceleration at bow	Vertical acceleration at bridge	Slamming	Propeller emergence	Bow deck wetness
24	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
25	0.68	0.73	0.99	0.94	0.99	0.99	0.95	0.91	0.90
26	0.86	0.99	0.99	0.95	0.99	0.99	0.95	0.91	0.89
27	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
28	0.86	0.99	0.99	0.95	0.99	0.99	0.95	0.91	0.90
29	0.67	0.72	0.99	0.95	0.99	0.99	0.95	0.91	0.90
30	0.86	0.99	0.99	0.95	0.99	0.99	0.95	0.90	0.89
31	0.88	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
32	0.86	0.99	0.99	0.95	0.99	0.99	0.95	0.91	0.89
33	0.69	0.75	0.98	0.94	0.99	0.99	0.95	0.92	0.90
34	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
35	0.88	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
36	0.88	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
37	0.87	0.99	0.99	0.95	0.99	0.99	0.95	0.91	0.90
38	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
39	0.86	0.99	0.99	0.95	0.99	0.99	0.95	0.91	0.89
40	0.87	0.99	0.98	0.94	0.99	0.99	0.95	0.92	0.90
41	0.86	0.99	0.99	0.95	0.99	0.99	0.95	0.91	0.89
42	0.88	0.99	0.98	0.94	0.99	0.99	0.95	0.93	0.91
43	0.87	0.99	0.98	0.94	0.99	0.99	0.96	0.92	0.90
44	0.87	0.99	0.98	0.95	0.99	0.99	0.95	0.92	0.89
45	0.89	0.99	0.98	0.94	0.99	0.99	0.96	0.94	0.92
46	0.89	0.99	0.98	0.94	0.99	0.99	0.96	0.94	0.92

The calculated values of the E factor for all solution variants are contained within the range of 0.67÷0.89. The detail calculation results are presented in Tab.2 as well as in Fig.5, 6 and 7.

The calculated E factor values contained in Tab. 2 indicate that the following seakeeping qualities have decisive influence on limitation of values of that factor for all considered design variants : rolling, heaving, slamming, propeller emergence, bow deck wetness however on reaching the maximum values of that factor :

- ⇨ pitching
- ⇨ vertical accelerations at the bridge
- ⇨ vertical accelerations at the bow

have the greatest influence.

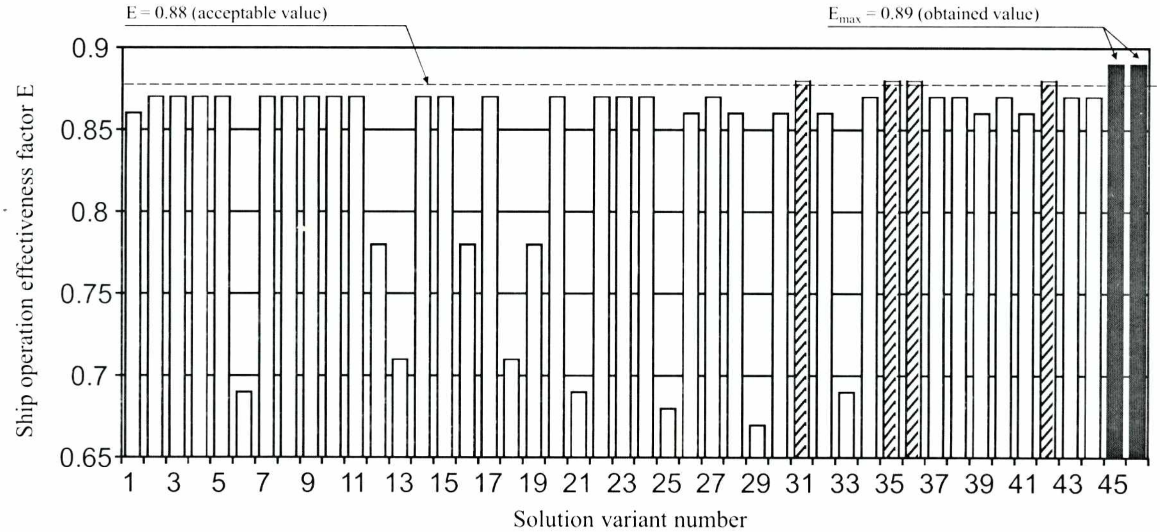


Fig.5. Values of the ship operation effectiveness factor E for the considered design variants

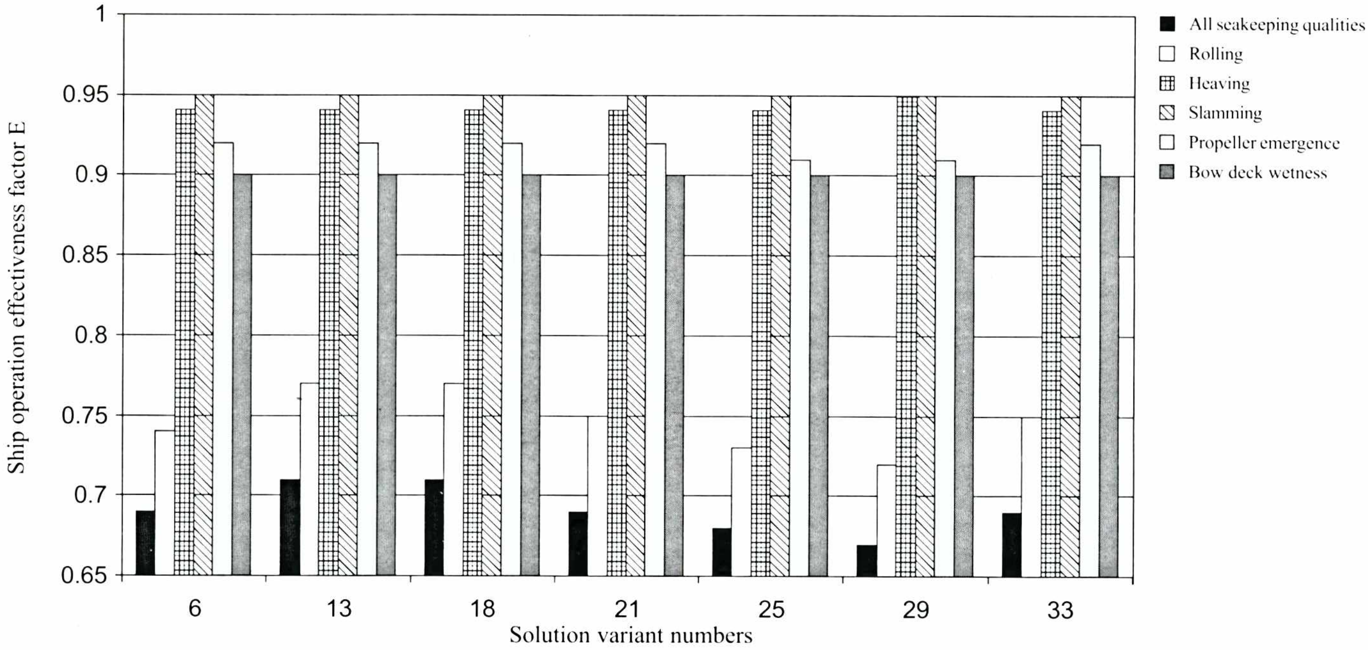


Fig.6. Design variants having the smallest values of the ship operation effectiveness factor E

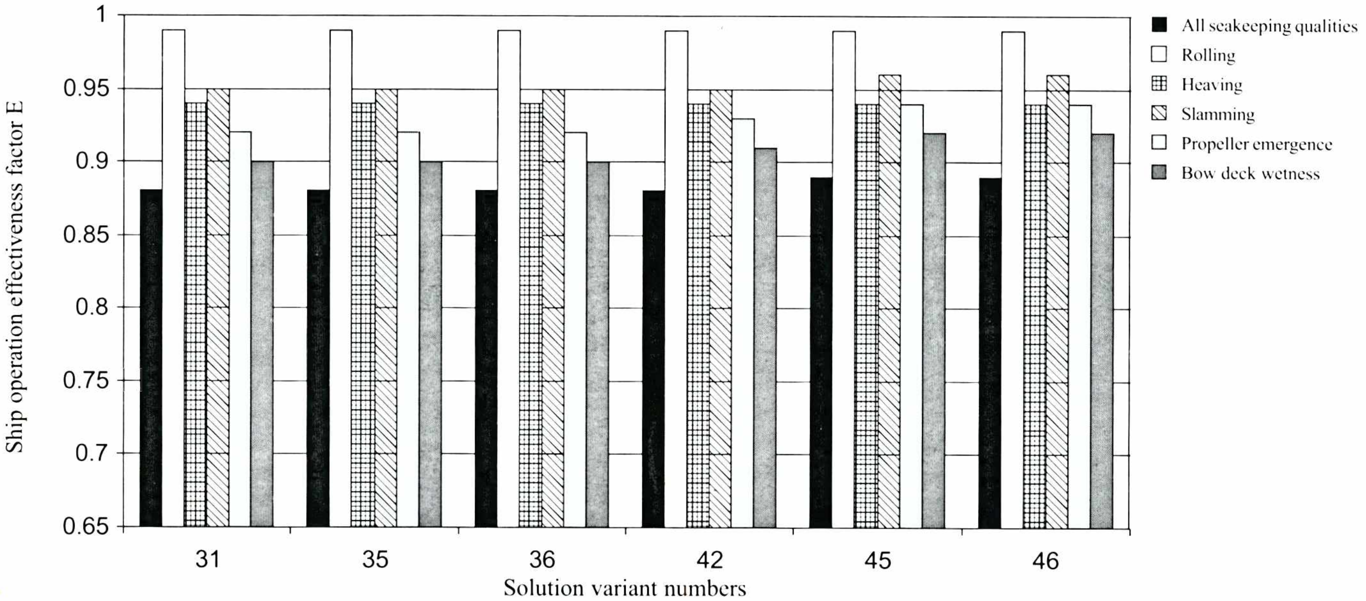


Fig.7. Design variants having the largest values of the ship operation effectiveness factor E

The design variants characterized by the smallest values of *E* factor, hence by the worst seakeeping qualities, are indicated in Fig.6. The data show that mainly ship rolling is of important influence on limitation of *E* factor values.

Fig.7. provides numbers of the design variants characterized by the best seakeeping performance (i.e. the largest values of *E* factor). Worthmentioning, that for this group of design variants the limitation of *E* factor values is mainly due to bow deck wetness, propeller emergence, heaving and slamming. Moreover these design variants are characterized by the largest values of *E* factor with regard to rolling.

Out of the group of the variants of the largest values of *E* factor (Fig.7) two variants (no.45 and 46) deemed optimum ones with regard to seakeeping ability, were selected. Their design parameters are shown in Tab.3.

***Tab.3.** The finally selected optimum ship design variants regarding seakeeping ability*

Variant	L [m]	B [m]	d [m]	H [m]	C_B [m]
45	173.8	28.85	12.17	16.67	0.6511
46	173.8	28.97	12.02	16.47	0.6567

In Fig.2. *B-L* and *d*-C_B domains are shown for the compromise design solutions obtained in the first and second phase of the optimization process, as well as the points representing two finally selected optimum solutions.

Conclusions

- The multicriterial optimization method applied in the first step of the presented design procedure can be deemed a very useful tool for investigation of influence of different design criteria on ship's qualities. However it should be remembered that the assumed constraints and weighting factors play an important role in that method.
- The presented example calculations of the selected seakeeping qualities and values of the ship operation effectiveness factor *E* for ships in waves showed that the compromise (equivalent) design solutions obtained from the first step of the optimization much differed to each other regarding ship seakeeeping ability. In the second phase of the optimization procedure it was possible to select the best design variants from the point of view of ship's seakeeping ability.

- The proposed approach made it possible to considerably reduce, during the second phase, the compromise solution domain obtained in the first phase (Fig.2). Choice of the best design variant does not worsen other ship qualities resulting from the criteria (especially economical ones) assumed for the first phase.
- The presented approach make it also possible to investigate ship seakeeping ability – by using artificial neural networks – already at the preliminary design stage and to elaborate design and operational guidelines for a considered ship.

Appraised by Jan Kulczyk, Assoc.Prof.,D.Sc.

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FOREIGN *conference*

MA SR – 2002

On 2-5 July 2002 the International Scientific School on :

Modelling & analysys of safety & risk in complex systems

had place in Saint-Petersburg (Russia).

Institute of Problems of Mechanical Engineering, Russian Academy of Sciences (RAS) was the main organizer of the scientific meeting in which experts from 12 countries including USA and Republic of South Africa, took part.

The meeting programme contained 96 papers presented during 4 plenary and 3 topical sessions as follows :

⇒ Capital markets risk
⇒ Risk in engineering and ecology
⇒ Risk theory and decision making.

Polish scientific workers presented two papers :

- **within 1st plenary session :**
  Reliability and risk evaluation of large systems
  by J. Jaźwiński (Air Force Institute, Warsaw),
  K. Kołowrocki (Gdynia Maritime University) and
  Z. Smalko (Warsaw University of Technology)
- **within the session on „Risk theory and decision making"** :
  Parallel-series multistate systems of any order
  by A. Cichocki (Gdynia Maritime University).

Conference

Days of Cooling

The Poznań Division of Cooling and Air-Conditioning Section, Polish Society of Mechanical Engineers (SIMP) has been distinguished from among Polish scientific workers and engineers - practicioners in this area by being engaged in organization of already traditional, specialty conferences under common heading : *Days of Cooling*. The last, already 34[th] conference of the kind had place in Poznań on 10-11 September 2002. Its programme contained 26 content-reletad papers most of which were devoted to analyzes of operation of different refrigerating and air conditioning devices, including also 8 theoretical papers, 4 - on research topics and 4 - on operational practice.

Out of 10 remaining papers each two dealt with :

- selection of devices
- control and regulation and thermoelectrical systems
- legal provisions

and, single presentations were devoted to :

- fluidization in air conditioning
- fluidization in cooling
- refrigerating transport
- preservation techniques.

The Conference had also a historical overtone as in the opening paper 40-year activity of the Poznań Division of Cooling and Air Conditioning Section, SIMP was presented . During this long period of time the activity of the Section's members was amounted to :

⇒ organizing special trainings for employees of production and repair enterprises
⇒ taking part in educational processes in high schools and universities
⇒ carrying out cycles of lectures devoted to design, assembling, repair and operational problems
⇒ arranging cooperation with cooling and air conditioning industry
⇒ organizing technical training trips
⇒ elaboration of expertises and special documentations
⇒ contributing to preparation of specialty handbooks and guidances
⇒ organizing exhibitions of special equipment and devices
⇒ arranging and developing contacts with foreign scientific workers and manufacturers (a.o. by participation in specialty conferences abroad).

A concept of organization of cyclic conferences under heading : *Days of Cooling* emerged in 1965. The first conference of the kind took place already a year later, and a wide interest was showed to the initiative. Since then it has been much done to make every sucessive conference of higher and higher content-related level and wider and wider range. As a result more and more interest has been paid to them, and with time apart from representatives of domestic industry and scientific institutions also participants from abroad (a.o. Great Britain, Bulgaria, Austria, Germany, Denmark, Belgium and Hungary) have begun to take part in the conferences.

Therefore it can be respectfully stated that the past 40 years were not wasted by the experts in cooling and air conditioning from Poznań.