Service margin - solution of the problem or a problem waiting for solution ?

Janusz Stasiak, D.Sc., Eng.

ABSTRACT

Subject of the paper is the problem of predicting sea-going ship resistance and/or horsepower in real operating conditions. Attention is drawn first of all to the need and possibility of revising the very much outdated but still used "service margin" method, which consists in adding an arbitrary percentage margin to the value of resistance or horsepower, relatively precisely determined for the calm water conditions. A negative impact in this respect is shown of the generally used delivery-acceptance procedures, where particular importance is attached to the ship propulsion tests on the "measured mile". The need of revising the "service margins" is a consequence of an obvious need for most efficient ships from the technical as well as economic point of view. Secondly, it is a "must" of permanent improving the ship design quality - the adequacy and accuracy of design methods. The work presents the "wave service margin" coefficient models. It is assumed that they may contribute to the necessary rationalization of the procedure of real ship resistance and/or horsepower determination. The work is based on the results of resistance tests of a series of ships designed within the Baltecologicalship project. The tests were carried out in the Chair of Ship Theory and Design of the Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology.

Keywords : sea-going ship, design, seagoing qualities, resistance, main propulsion horsepower, service margins

INTRODUCTION

The role of ship hydromechanics in ship design

There is no doubt that the hydromechanical properties of a sea-going ship are a fundamental quality (a set of qualities) of the craft. They determine its physical substance and, to a large extent, its functional effectiveness. It seems therefore fully justified to think that ship design, aimed at creating the best possible ship, will be particularly receptive to all the existing test models and will stimulate development of more and more adequate and precise models.

However, in the confrontation with reality that may appear to be wishful thinking. In fact, the ship design methods have been based for decades on the same hydromechanical solutions developed at the end of the 19th and beginning of the 20th century. The later developed solutions, quite useful and definitely of better quality, have not been appropriately used in design. As that pertains to the basic and vital ship characteristics, such as transverse stability, load-lines, unsinkability and the resistance-propulsion properties, it is difficult to qualify the ship design as a modern and professional practical speciality. One can hardly expect its products to be, as a rule and not only by accident, as good as they can objectively be.

Therefore one has to agree, though regretfully, that :

„*The naval architecture is a science of vague assumptions, based on debatable figures taken from inconclusive instruments, performed with equipment of problematical accuracy by persons of doubtful reliability and questionable mentality*” [a)].

That opinion has to be accepted because in the more and more institutionalized and bureaucratic shipbuilding and shipping system there are no signs of will and action aimed at changing the situation. On the contrary, quite clear are mechanisms and tendencies of maintaining the status quo in this respect.

The problem discussed here is also important as it is related to the theory of ships - a research and practical science, by definition aimed at creating new more accurate and practically useful models of hydromechanical phenomena. Lack of demand from the practical design causes decreasing interest in creating such models and concentration on the in fact ineffective „polishing” of the hydromechanical solutions used in ship design procedures for years. That particular pragmatism[b)] of the theory of ships closes the „positive feedback” cycle, which effectively petrifies and even deepens the hydromechanical backwardness of shipbuilding.

Service margin

The above characterised situation is reflected in predicting the ship service resistance and/or horsepower. Now, like in the past decades, the main design and research effort is concentrated on the idealised part of the problem, related only to the calm water conditions. Ship resistance and/or horsepower in real sea conditions is treated „marginally”: they are not used as the hull size and shape selection criteria and their values are roughly predicted by means of a „service margin”. The „service margin” method is the simplest of all the possible ways of predicting the real values of resistance $\mathbf{R_{TS}}$ $(\mathbf{V_E})$ and/or the ship main propulsion horsepower $\mathbf{P_{TS}}$ $(\mathbf{V_E})$ typical of the normal sea conditions and the required service speed $\mathbf{V_E}$. It consists in determining those values as a product :

$$R_{TS}(V_E) = (1+k_w) \cdot R_T(V_E)$$

or : (1)

$$P_{TS}(V_E) = (1+k_w) \cdot P_T(V_E)$$

where :

- $\mathbf{R_T(V_E)}$ or $\mathbf{P_T(V_E)}$ are the ship calm water resistance or horsepower values, respectively, for the speed $\mathbf{V_E}$
- $\mathbf{k_w}$ is a dimensionless resistance and/or horsepower reserve (margin) coefficient, whose values are determined by a rather subjective selection from the $\mathbf{k_w} \in (0.15 ; 0.35)$ range.

In the past, up to mid 1960s, the so defined „service margin” method was a justified practical design approach. At that time it was the only practical solution of the complex and important problem, not yet investigated and, needless to say, modelled. Sticking to that method later when much more accurate and useful real sea resistance (horsepower) prediction design tools became available[c)] has been a mere ship design

„shop floor neglect". More importantly, that has been a neglect with an evident effect - the resistance and horsepower „oversize" ships.

As it was demonstrated (e.g. in [1, 2, 3]), ships designed in the mid-twentieth century did not use in service ca. 20% of their installed horsepower, whereas their average (taken from several dozen sea trips) service speed was in the range of 60% to 103% of the design speed. In the course of years, when the cargo ship design speed and horsepower increased quickly, the oversizing problem was becoming (it had to become) more and more clear. It gained importance also because of the significant improvement of ship hull construction technology.[d] Therefore, practical economic indications could be seen to rationalize the design methods - to include the seagoing qualities into the ship hull design criteria or at least to reduce the service margins. It could have been expected that such revision would soon become a fact. Nothing of the sort has ever happened.

Still a lot is being done in the ship design process to find a hull shape with a still water resistance lower by so much as a fraction of percentage point; the seagoing qualities of such ship are generally a second-rate matter, most often totally neglected. And still the so scrupulously minimized resistance is then roughly increased by a **15** to **35 percent** service margin. Therefore, it may and should be assumed that even modern sea-going ships „carry" at least a dozen or so percent reserve of never used main propulsion system horsepower.

The ship delivery-acceptance procedure

It seems that the reasons of such a deformed situation in the ship design resistance and/or horsepower prediction question should be sought first of all in the firmly established and institutionalized ship delivery-acceptance procedures, where a particular role is assigned to the ship speed (propulsion capability) test on the measured mile.

That test, intended to be an objective verification of real propulsive and speed qualities of the ship, in fact does not provide such a verification. It does stimulate, however, working out such design resistance-propulsion characteristics which meet the respective contract requirements in the test (still water) conditions. For the shipyard, negative result of that test means a sure financial loss determined in the contract. On the other hand, designing a ship having the resistance-propulsion characteristics well suited to the typical operating conditions, regardless of the measured mile test results, does not bring the shipyard (designer) any additional financial profits.

As long as such a ship acceptance procedure is in use, one should not expect any significant changes (rationalizing) in designing the ship resistance-propulsion properties. Taking into account :

- strong adherence of the shipbuilding and shipping industry to the generally accepted solutions, particularly those of the administrative and legal character
- objectively illusory but individually irrefutable conviction on the part of the owner of the necessity of checking the ship performance characteristics at the moment of delivery
- an evident interest of the shipyard and designer in applying a sanctioned service margin with its broad range of values, in order to „hide" all the inaccuracies of the resistance and horsepower predictions,

it will take long for any changes in this respect to occur. Therefore, it may be assumed that the service margin will still be used in the ship design procedure for a long time.

In this situation, what can and should be reasonably done is **constant updating of the service margin values** – improving the accuracy of their **k_w** coefficients. This task belongs to the domain of the theory of ships. It is an immanent duty of that speciality to generate more and more adequate models of all those hydromechanical phenomena which determine the functioning of ships. That duty is absolutely indispensable in relation to the phenomena and problems connected with the ship safety and operational efficiency.

The purpose and subject of investigation

Apart from the above presented remarks, the purpose of this paper is also to present some real possibilities of determining more adequate values of the service margin coefficient **k_w**. Those possibilities in general consist in making an effective use of the **seakeeping ability methods**. In particular, they consist in **generalization of the long-term prognosis of additional ship resistance** from sea waves **R_{AV}**.

It seems that the so obtained expressions of the type :

$$\frac{R_{AV}}{R_T} = f\left(Fn_E, K\right) \qquad (2)$$

where :

R_T - is the ship still water resistance, $Fn_E = \frac{V_E}{\sqrt{g \cdot L}}$ is a dimensionless design ship speed and **K** represents the ship hull governing geometric characteristics, may be correct measures, if not the total **k_w** coefficient then at least its very important component **k – the service margin wave part coefficient**.

One way or another, such expressions may be an important contribution to the necessary rationalization of the service margin values.

The paper is based on the results of ship resistance tests carried out in the Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology, in the „Baltecologicalship" project and is an additional summary of those tests. The test materials are presented and discussed in detail in [5, 6, 7, 8].

LONG-TERM PROGNOSIS OF THE INCREASED RESISTANCE OF A SHIP MOVING IN HEAD WAVES

Definitions

- The ship resistance increase (additional resistance) was predicted (determined) only for the **head sea conditions** i.e. for wave incidence angle **β** equal to **180°**.
- **The long-term prognosis of resistance increase** (additional resistance from sea waves) **R_{AV}** of a ship moving with constant speed **V** were determined as probabilistic estimation of a mean value of a set of random short-term additional resistance **R_{AW}(x)** prognosis for that ship :

$$R_{AV} = \sum R_{AW}(x) \cdot p(x) \qquad (3)$$

where :

  - **x = {a, b, c}** is a set of discrete random **sailing conditions**, which have assigned to them the resistance increase values **R_{AW}(x)** determined as short-term prognosis. Elements of the **x** set are: ship loading conditions [**a**], sailing regions [**b(b_1,b_2)**] – seas (**b_1**) and their regions (**b_2**) and sea states – wave conditions (**c**) characteristic of those seas
  - **p(x)** = **p(a)** · **p(b)** · **p(c|b_1)** is a probabilistic model of conditions **x**, or the combined probability function of discrete random variables **a, b,** and **c**.

➢ **The short-term prognosis of resistance increase R_{AW} (x)** (prognosis of resistance increase in the stationary irregular wave conditions) were determined in accordance with the principle of superposition expressed as follows :

$$R_{AW}(x) = 2\int_{\omega} r_{AW}(\omega, a)\cdot S(\omega, b, c)\cdot d\omega \qquad (4)$$

where :

- r_{AW} (**ω , a**) is a dimensionless resistance increase coefficient (resistance increase operator) determined from ship **model tests** carried out in regular head waves of different frequencies **ω**
- **S** (**ω**, **b, c**) is a model of the spectral density function of stationary irregular waves, the form of which was :
    - assigned to a sea region b_2. For restricted (coastal) waters – the JONSWAP spectrum, for unrestricted (open) waters – the ISSC spectrum
    - identified each time by the sea state characteristics $c = c(H_{1/3}, T_1)$: significant wave height $H_{1/3}$ and characteristic period T_1.

➢ **The resistance increase prognosis** were prepared for :

- shipping routes in the **North Sea** and **Baltic Sea** regions, whose probabilistic model **p**(**b**) was based on the Author's knowledge
- random stationary waves, whose probabilistic model $p(c) = p(H_{1/3}, T_1)$ was based on the information taken from the „Global Wave Statistics" atlas [4]
- three ships with two loading conditions [light (a_1) and heavy (a_2)] described by the model **p**(**a**) assumed by the Author
- three speeds **V** of each ship. The speed values were in the range $V \in < 0.65V_E ; 1.1V_E >$ where V_E is the nominal (design) service speed of each ship.

Determination procedure of the long-term R_{AV} prognosis

The determination procedure of a single (for a given ship and its constant speed **V**) R_{AV} prediction, as described by expressions (3) and (4), was the following :

→ In the **first stage** the functional relations: $r_{AW} = f(\varpi|_{Fn})$ were determined, where : $\varpi = \omega(L/g)^{1/2}$ is a dimensionless wave frequency determined in a stationary system.
The relations were based on the results of model tests carried out with **1:85** scale ship models towed in calm water and on ca. 15 regular waves, whose frequencies **ϖ** were in the $\varpi \in (1.5 , 5.0)$ range.

→ In the **second stage** the R_{AW} prognosis were calculated in accordance with expression (4).
The R_{AW} values were calculated for stationary waves (sea states) **c** (T_1 , $H_{1/3}$) :

- whose T_1 and $H_{1/3}$ characteristics were taken from the $T_1 \in < 4s ; 10s >$, $H_{1/3} \in < 0.5m ; 6.5m >$ ranges
- whose spectral density function **S** (**ω**, T_1, $H_{1/3}$), depending on sea region, is modelled by :
    - for **coastal waters** – the ISSC spectrum in the form :

$$S(\omega, T_1, H_{1/3}) = \frac{173 \cdot H_{1/3}^2}{T_1^4 \cdot \omega^{-5}} \cdot \exp\left(-B \cdot \omega^{-4}\right)$$

- for **open waters** – the JONSWAP spectrum in the form proposed by the Author :

$$S_J(\omega, T_1, H_{1/3}) = \frac{1}{2} S(\omega, T_1, H_{1/3}) \cdot$$
$$\cdot 3.3^{\exp\left[-80\cdot\left|0.2069\cdot\omega\cdot T_1 - 1\right|^{2.5}\right]}$$

where : **S** (**ω**,T_1,$H_{1/3}$) is a model of the ISSC spectrum.

→ In the **third stage**, using expression (1), the R_{AV} prognosis were calculated.
The R_{AV} values for each ship and for each selected speed **V** were calculated by means of a **probabilistic model of all-year sailing conditions**, whose elements are :

- ship loading condition probability function **p**(**a**) presented in Tab.1
- sailing area probability function **p**(**b**) presented in Tab.2
- sea state probability function $p(c|b_1) = p(T_1,H_{1/3}|b_1)$ for the NORTH SEA presented in Tab.3
- sea state probability function $p(c|b_1) = p(T_1,H_{1/3}|b_1)$ for the BALTIC SEA presented in Tab.4.

Table 1

Loading condition $p(a_i)$		
light a_1	heavy a_2	Σ
0.800	0.200	1.000

Table 2

Sea areas	North Sea	Baltic	Σ
Restricted	0.150	0.100	0.250
Open	0.450	0.300	0.750
Σ	0.600	0.400	1.000

Table 3

Heights $H_{1/3}$ [m]	Periods T_1 [s]							Σ
	4	5	6	7	8	9	10	
0.5	0.019	0.084	0.092	0.041	0.010	0.002	-	0.248
1.5	0.003	0.048	0.120	0.096	0.037	0.010	0.002	0.316
2.5	0.001	0.017	0.061	0.071	0.039	0.013	0.003	0.205
3.5	-	0.006	0.027	0.038	0.024	0.010	0.003	0.108
4.5	-	0.002	0.011	0.018	0.014	0.006	0.002	0.053
5.5	-	0.001	0.004	0.009	0.007	0.004	0.001	0.026
6.5	-	-	0.002	0.004	0.004	0.002	0001	0.013
Σ	0.023	0.158	0.317	0.277	0.135	0.047	0.012	0.969

Table 4

Heights $H_{1/3}$ [m]	Periods T_1 [s]							Σ
	4	5	6	7	8	9	10	
0.5	0.093	0.140	0.075	0.020	0.003	-	-	0.331
1.5	0.033	0.130	0.130	0.060	0.014	0.003	0.001	0.371
2.5	0.006	0.045	0.068	0.040	0.013	0.003	0.001	0.176
3.5	0.001	0.011	0.020	0.015	0.007	0.002	-	0.056
4.5	-	0.002	0.006	0.005	0.002	0.001	-	0.016
Σ	0.133	0.328	0.299	0.140	0.039	0.009	0.002	0.950

Ships

The resistance increase predictions were determined for three ships, with their main characteristics presented in Tab.5.

Table 5

Ship characteristics	Symbol	Tanker		Container carrier		Ro - ro ship	
		light loaded ship	**heavy loaded ship**	**light loaded ship**	**heavy loaded ship**	**light loaded ship**	**heavy loaded ship**
Length between perpendiculars	L [m]	132.00		132.00		147.75	
Length on waterline	L_W [m]	131.77	132.18	129.28	132.00	145.24	147.50
Breadth	B [m]	22.50		22.50		24.80	
Draught	d [m]	8.00	8.70	7.60	8.55	6.00	6.50
Depth	D [m]	12.80		11.20		14.00	
Displacement	∇ [m^3]	17512	19375	15138	17528	13899	15940
Block coefficient	C_B [-]	0.737	0.750	0.671	0.690	0.632	0.650
Coefficient of fineness	C_W [-]	0.884	0.906	0.845	0.869	0.855	0.868
Service speed	V_E [kn]	14.00		16.50		19.50	
Dimensionless longitudinal radius of gyration	k_{yy}/L [-]	0.250		0.250		0.250	

It can be seen that in the NORTH SEA :

- annual mean wave parameters are : $\mathbf{T_1} = 6.35$ s ; $\mathbf{H_{1/3}} = 1.95$ m
- calm water occurs with probability $\mathbf{p} = 0.031$ i.e. approx. 11 days in a year.

It can be seen that in the BALTIC SEA :

- annual mean wave parameters are: $\mathbf{T_1} = 5.36$ s ; $\mathbf{H_{1/3}} = 1.43$ m
- calm water occurs with probability $\mathbf{p} = 0.050$ i.e. approx. 18 days in a year.

Results of the calculations

Table 6 presents the values of :

- mean still water resistance $\mathbf{R_T} = 0.8\mathbf{R_{TL}} + 0.2\mathbf{R_{TC}}$ (where $\mathbf{R_{TL}}$ and $\mathbf{R_{TC}}$ are still water resistance values in the light and heavy loading condition, respectively)
- long-term prognosis of resistance in waves $\mathbf{R_{AV}}$
- total mean resistance in waves $\mathbf{R_{TV}} = \mathbf{R_T} + \mathbf{R_{AV}}$
- respective relative increases : $\frac{R_{AV}}{R_T}$ and $\frac{R_{AV}}{R_{TV}}$

determined for 3 speeds **V**
of each ship characterised in Tab.5.

$$\text{where : } C_B = \frac{\nabla}{L \cdot B \cdot d} \;\; ; \;\; C_W = \frac{S_W}{L \cdot B}$$

Table 6

	Tanker			Container carrier			Ro - ro ship		
V [w]	9.8	12.6	15.4	11.5	14.2	16.9	12.5	16.4	20.3
Fn [-]	0.140	0.180	0.220	0.164	0.203	0.242	0.169	0.222	0.274
R_T [kN]	180	360	635	270	420	680	215	390	810
R_{AV} [kN]	56	76	83	57	65	72	46	50	54
R_{AV} [kN]	236	436	718	327	485	752	261	440	864
$\frac{R_{AV}}{R_T}$ [%]	31	21	13	21	15	11	21	13	7
$\frac{R_{AV}}{R_{TV}}$ [%]	24	17	12	17	13	10	18	11	6

The $\mathbf{R_{AV}}$ values were determined in accordance with procedure described at the page 31, and the $\mathbf{R_{TL}}$ and $\mathbf{R_{TC}}$ resistance values were determined from model test results recalculated for a real ship by the three-dimensional extrapolation method.

Long-term prognosis of the relative increase of resistance in waves - wave service margin

Figure presents a coefficient function $k = \frac{R_{AV}}{R_T} = f(Fn)$ built from the respective values taken from Tab.6 :

- **points** (different for different ships) mark the $k = \frac{R_{AV}}{R_T}$ values taken directly from Tab.6
- **full line** marks a universal function for the ships in question and their speeds, of the following mathematical form identified here :

$$k = \frac{R_{AV}}{R_T} = \frac{0.0635}{Fn} - 0.157 \qquad (5)$$

$$\text{where : } Fn \in \; < 0.12 \; ; \; 0.30 >$$

The expression (5), with the assumption that :

$$Fn \equiv Fn_E = \frac{V_E}{\sqrt{g \cdot L}}$$

may also be treated as a certain model of a **dimensionless coefficient (k) of the wave service margin**, i.e. coefficient being a **component** (part) of the coefficient $\mathbf{k_W}$ [see expression (1)], which determines the ship resistance and/or horsepower margin balancing the expected (in the long-term prognosis sense) increase $\mathbf{R_{AV}(V_E)}$ [or $\mathbf{P_{AV}(V_E)}$] caused exclusively by the sea waves.

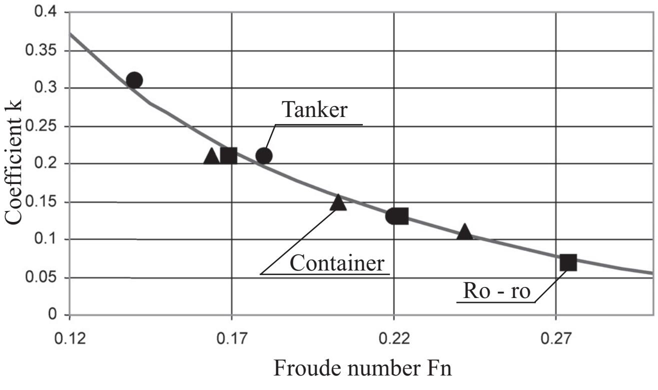

Fig. *Expression* $k = \frac{R_{AV}}{R_T} = f(Fn)$

An alternative version of model (5) is the expression :

$$\boxed{k_1 = \frac{R_{AV}}{R_T} = 0.91 \cdot C_B - 0.50} \qquad (6)$$

$$\text{for} \quad C_B \in < 0.50\,; 0.85 >$$

where: $C_B = \frac{\nabla_E}{L \cdot B \cdot d_E}$ is the design block coefficient (corresponding to the design values of $\mathbf{\nabla_E}$ and $\mathbf{d_E}$).

Model (6) was identified here by substituting to model (5) an expression :

$$Fn_E = \frac{0.070}{C_B - 0.377}$$

devised by the Author and very close (qualitatively and quantitatively) to the well known Ayre's formula :

$$C_B = 1.075 - 1.68Fn_E$$

In order to illustrate the obtained results, Tab.7 presents percentage values of the **k** and $\mathbf{k_1}$ wave service margin coefficients, calculated :

- according to models (5) and (6)
- for ships characterised in Tab.5, where values of the $\mathbf{C_B}$ coefficients for those ships were determined as their long-term prognosis, i.e. as weighted averages of the $\mathbf{C_B}$ values corresponding to the light (80 %) and heavy (20 %) loading condition.

Table 7

	Tanker	**Container carrier**	**Ro-ro ship**
C_B [-]	0.740	0.675	0.636
V_E [kn]	14.00	16.50	19.50
Fn_E [-]	0.200	0.236	0.263
k model (5)	**16 %**	**11%**	**8%**
$\mathbf{k_1}$ model (6)	**17%**	**11%**	**8%**

CONCLUDING REMARKS

It is fitting to underline the following aspects in the summary :

- The intention of this paper is to draw attention to the needs and possibilities of :
  - constant improvement of the quality and quantitative accuracy of the ship theory and design methods
  - more frequent application, in ship theory and in practical ship design, of the useful but still little used models of ship hydromechanics - the **seagoing qualities** in particular.
- It was particularly intended to remind that such an important design problem as prediction of optimum ship resistance and/or horsepower in real operating conditions still remains a **problem waiting for solution**.
- An important objective of the work was also to indicate a possibility of identifying more justifiable service margin formulae based on **generalisation of long-term prognosis of the relative additional ship resistance in waves**.
- The identified models (5) and (6) do not aspire to be complete and directly applicable design service margin formulae, as they :
  - are based on too scarce research material, and also
  - are modelling only the wave part of the problem.
- The above mentioned limitation of models (5) and (6) is to some degree compensated by the fact that their results are an **upper estimation** of the wave service margin. They were identified :
  - only for the **head sea conditions** when the resistance increase is the greatest
  - without taking into account the **voluntary speed (and horsepower) reduction** and/or change of the ship course in order to protect the ship against too intense (dangerous) motions - accelerations, vibrations, slamming, shipping of water etc.
- The form of models (5) and (6) shows clearly that the **k** coefficient depends either on the ship **design speed** $\mathbf{V_E}$ or on the **design values of block coefficient** $\mathbf{C_B}$:
  - it is inversely proportional to $\mathbf{V_E}$
  - it is directly proportional to $\mathbf{C_B}$.

BIBLIOGRAPHY

1. Aertssen G., Sluys M.F.: *Service Performance and Seakeeping Trials on Large Containership*. Naval Architect, October 1972
2. Levine H., Hawkins S.: *Comments on Service Margin for Ships*. SNAME. Technical and Research Rep. 1970
3. Zubaly R.B.: *Causes and Extent of Lost Time at Sea for Dry Cargo Ship*. SNAME, Technical and Research Rep. 1969.
4. Hogben N., Dacunha N.M.C., Olliver G.F. : *Global Wave Statistics*. BMT 1986
5. Brzoska E. et al.: *Still water resistance model tests and propulsion prediction of the SINE 202 container carrier* (in Polish). Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology. Gdańsk, 2003
6. Brzoska E. et al.: *Resistance in waves prediction of the SINE 202 container carrier* (in Polish). Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology. Gdańsk, 2003
7. Brzoska E. et al.: *Resistance model tests and propulsion prediction of the SINE 203 tanker in still water and in waves* (in Polish). Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology. Gdańsk, 2003
8. Brzoska E. et al.: *Resistance model tests and propulsion prediction of the SINE 204 Ro-Ro ship in still water and in waves* (in Polish). Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology. Gdańsk, 2003

---

a) Author of the sentence unknown

b) There is a strong conviction that the work of research and practical sciences may be appreciated only when it is concentrated on fulfilling the existing and not potential design needs

c)
- „superposition principle" published in 1953 by St. Denis and Pierson and its application to the resistance-propulsion problems published in 1967 by Vassilopoulos
- standard spectral (spectral density function) wave models, e.g. the Pierson-Moskowitz model recommended in 1969 by ITTC
- atlases of annual wave distributions in the main shipping sea areas, e.g. the „Ocean Wave Statistics" atlas published in 1967 by Hogben and Lamb

d) The problem is that the service margin is meant to be a remedy not only for the increased ship resistance (horsepower) due to sea-way but also due to the uncontrolled and gradually increasing hull roughness. There is no doubt that with totally welded hull shell (and constantly improved welding methods) and with a constant progress in the quality, durability and anti-fouling effects of paint coatings, also the „roughness" component of the service margin should be revised (reduced)