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The assessment of the hull geometry influence on seakeeping characteristic

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Abstract

The modified Bales-Wijngaarden seakeeping index has been used for the comparison of seakeeping performance of diverse hulls.
The hull shape family has been generated and seakeeping calculations were conducted for this family.
The results of the calculations were transformed into modified Bales-Wijngaarden index form. The influence of hull geometry on the seakeeping index has been presented in the form of threedimensional diagram as well as the multiple regression equations.

1 Introduction

Within the framework of design methodology elaborated for certain types of offshore positioned vessels the need had appeared to create the means for the comparison of geometrically different hulls under various aspects.
As the part of this methodology the method for the judging of seakeeping behaviour of diving support vessels (DSV) was necessary.
To enable the comparison of diverse hulls it was decided to apply seakeeping index as suggested by Bales [1] and later developed by Wijngaarden [2].
The initial hull shape was derived basing on the statistical analysis of existing DSV's hulls. The hull form parameters under investigation were defined as:

volume of displacement V [m^3]

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length-breadth ratio	L/B
breadth-draugth ratio	B/T
block coefficient	CB

The volume of displacement has been chosen as V=4000 m^3, V=8000 m^3, V=12000 m^3. Then the basic pattern of 27 hull forms was generated for V=8000 m^3 with systematically varied:

L/B = 3,5; 4,5; 5,5
B/T = 2,5; 3,25; 4,0
CB = 0,6; 0,7; 0,8

2 The basic idea of seakeeping index

The seakeeping index is defined as nondimensional number dependent of hull geometry and integrating particular seekeeping responses under various seaway conditions. This index represents the hydrodynamical quality of particular hull form in relation to other hulls.
The index allows describe the huge amount of calculated or measured data by a single number incorporating the several seakeeping hull characteristics. The introduction as well as theoretical and experimental proving of the efficiency of this index was carried out by N. K. Bales in 1970-1980. The method applied by Bales consisted in ranking of particular response of several hulls (i.e heave amplitude, pitching amplitude vertical acceleration etc) relatively to the excellence of each hull. The model with the smallest amplitude was the best, the model with the largest amplitude was the worst. Then the particular responses were normalized by dividing the best response by the responses of individual models.
If the particular response was judged as more important the weight coefficient was applied. Since the rank index is a nondimensional number the integration was possible by direct summing of calculated normalized responses for each vessel and then rearranging in excellence scale of 1 to 10.
The idea of Bales was developed by Wijngaarden who observed that the hull response is seriously affected by the wave period. The frequency of the occurrence of specific wave periods is different for every sea area.
That means that seakeeping responses should be estimated for typical wave periods on given sea area and weighted with the probability of occurrence of this wave period.
It may be noted that according to Wijngaarden the seakeeping index can be expressed as

$$R = \frac{1}{N}\sum_{i=1}^{N} W_h(i)U_i \qquad [1]$$

where

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N-number of responses investigated

$W_h(i)$ - weight function emphasizing the importance of given kind of response for general hull evaluation.

$W_h(i)$ fulfils the condition:

$$\sum_{i=1}^{N} W_h(i) = 1$$

U_i - average weighted response of hull

$$U_i = \frac{\sum_{i=1}^{K} u_i w_u}{\sum_{i=1}^{K} w_u} \qquad [2]$$

where

w_u - weight function related to the frequency of the occurrence of specifical wave period

K - number of wave periods considered

For the evaluation of possible combination of hull form parameters multiple regression analysis was performed by Bales and the polynom was obtained

$$R = a_0 + \sum_{i=1}^{M} c_i G_i \qquad [3]$$

where

M - number of hull geometry parameters considered

G_i - hull geometry parameters

a_0 ,c_i - multiple regression coefficients

The seakeeping index R may be obtained by this formula without the performing of hull response calculation for every specified hull shape.
Obviously the polynom is valid for given hull form pattern as well as for given course angle.

3 The assumption for R index computation

The calculation of index R was performed for the comparison of some combinations of DSV hull form parameters.
It was assumed that following seakeeping responses will be taken into account:

- heave
- sway
- pitching
- relative motion
- vertical acceleration
- horizontal acceleration

The frequency of wave period occurrence typical for Beaufort 6 in North Sea area was considered as follows

wave period T_i [s^{-1}]	4	5	6	7	8	9
frequency of occurrence Q_i[%]	3.9	25.2	38.2	19.4	10	2.3

The WARES program was used for the computing of seakeeping responses.
The JONSWAP wave spectrum was used including 6 values of wave period; namely 4, 5, 6, 7, 8, 9 s and significant wave height $h_{w1/3}$=3 m.
The calculations were performed for six course angles namely 0, 20, 45, 90, 135, 180^0. It was assumed that 0^0 means the stern wave. The speed of the vessel V=0 (the positioning over the point).
It was also assumed that the hull forms were provided with bilge keels 300 mm high along 0,2 LBP.
The metacentric height GM=1,5 m for L/B =4,5÷5,5 and GM=1,8 m for L/B=3,5÷4,49 was assumed. The radii of gyration were calculeted according to the following relationships

$$K_{YY}/B=0,25$$
$$K_{XX}/LBP=0,36$$

The seakeeping prediction was made for the family of 27 hull forms with volume of displacement V=8000 m^3 and additionally for a few hull forms with volume of displacement V=4000 m^3 and V=12000 m^3 to assess the vessel size effect.

4 The results of calculation and modified seakeeping index idea.

The results obtained shown considerable diversification of seakeeping quality of particular models.
Generally speaking the models with high B/T ratio value are clearly better. The impact of L/B ratio is not distinct and can be estimated only together with B/T and CB. Some problems with global estimation of particular models had ensued as the result of computation of seakeeping index for each course angle separately.
To avoid these problems the seakeeping index was modified and defined as proportional to the area determined in polar coordinates system by the magnitudes of particular seakeeping indices at corresponding course angles.
The definition of the area under consideration depends on the dominating mode of vessel operation. For transport cargo vessel the index is usually determined for head wave.
In the case of diving suport vessels several alternatives may occur:

1. If the dominating mode of operation is the positioning over the point with maintaining at the head course $\beta = \pm 20^0$ in relation to weather direction-then magnitude of seakeeping index will be determined as the area as shown on Fig. 1.

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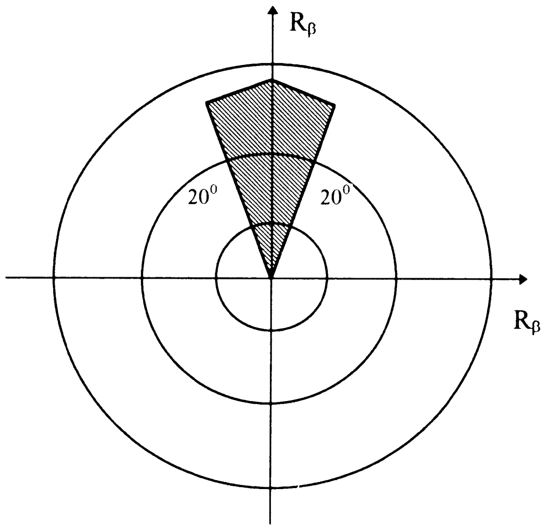

Figure 1: Seakeeping index for positioning mode with maintaining course angle $\beta = \pm 20^0$.

2. If main interest is to obtain vessel dimensions ensuring the best behaviour when hoisting/launching of big submersible at leeward side then seakeeping index may be defined as the area show on Fig. 2.

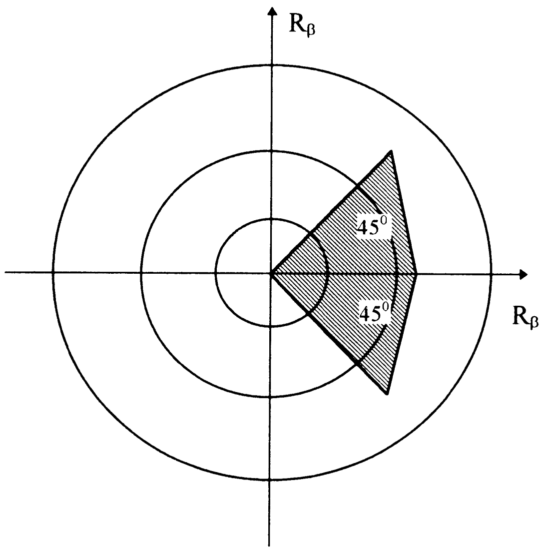

Figure 2: Seakeeping index for positioning mode with submersible hoisting/launching.

3. If the interest is to obtain optimal vessel dimensions at arbitrary wave direction then the seakeeping index is proportional to the area as shown on Fig. 3.

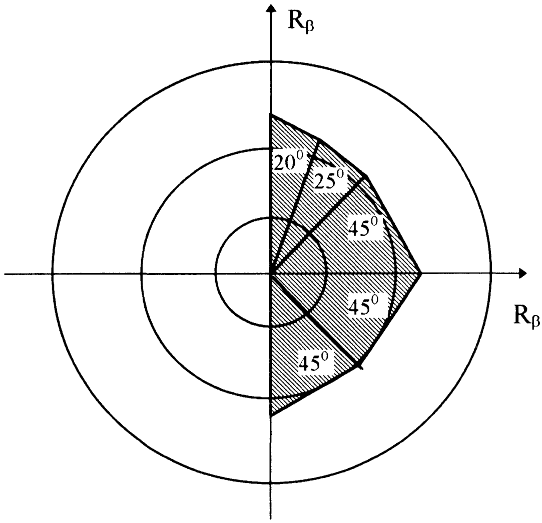

Figure 3: Modified seakeeping index (general).

The seakeeping index RA as shown on Fig. 3 was chosen for the needs of methodology mentioned in the Introduction. Such index was calculated for every form of 27 hulls family. After the computing and summing up of particular triangles area $A_{\beta i}$ to obtain polygon with the area A_i the ranking procedure was performed between 27 hull forms according to the formula:

$$RA = \left(\frac{A_i - A_{min}}{A_{max} - A_{min}} \right) 9 + 1 \qquad [4]$$

where

RA - modified seakeeping index (in scale from 1 to 10)
A_i - the area of polygon for the form under consideration
A_{min} - the area of the smallest polygon
A_{max} - the area of the largest polygon

The obtained results are shown on fig. 4.

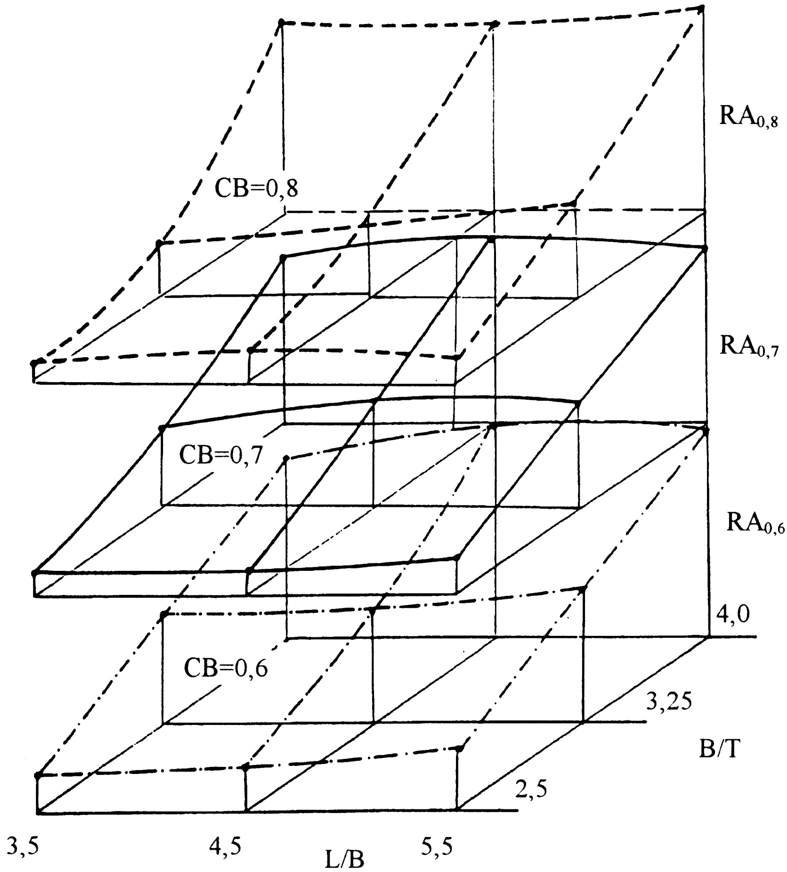

Figure 4: Modified seakeeping index as a function of L/B, B/T, CB (valid for the family 27 hulls at $V=8000\ m^3$).

To facilitate the evaluation of particular hull forms the multiple regression equation was derived

$$RA_{8000}=11,22+0,434L/B+4,995B/T+10,385CB-35,8CW \qquad [5]$$

where coefficient of determinaton $(R.SQ)_A=0,961$ and standard error SE=0,63.

In this equation the coefficient of waterline CW is occuring which may be not known in initial stage of design.

Then the following equation can be more convenient

$$RA_{8000}= -9,812+4,62L/B-4,399CB+0,627L/V^{1/3} \qquad [6]$$

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because only the parameters known at the begining of design process are used. For this equation are $(R.SQ)_A=0{,}959$ and $SE=0{,}64$. Both equations are valid for $V=8000\ m^3$.
The influence of the vessel displacement on the seakeeping index may be estimated by the introducing the correcting coefficient in the form

$$A_V\left(\frac{V-8000}{8000}\right) \qquad [7]$$

Then the equation for modified seakeeping index may be written as

$$RA_V = RA_{8000} + A_V\left(\frac{V-8000}{8000}\right) \qquad [8]$$

Since the effect of displacement on the seakeeping index has appeared nonlinear two correcting coefficients are used.
Then for $V<8000\ m^3$ will be

$$RA_V = RA_{8000} + 7{,}388\left(\frac{V-8000}{8000}\right) \qquad [9]$$

and for $V>8000\ m^3$ will be

$$RA_V = RA_{8000} + 13{,}588\left(\frac{V-8000}{8000}\right) \qquad [10]$$

5 Conclusion

The method presented can be used for the exploration of the most promising combination of DSV hull main dimensions concerning the predefined seakeeping response. Other sea conditions, responses, hull form parameters could be taken into account if necessary.

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