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The simplified stability criterion for open deck fishing boats

SUMMARY

To apply classification society survey to coastal fishing boats it is necessary to elaborate a simple but rational method for their stability assessment. The paper presents an approach to the stability assessment of such boats which can be applied in boat design and control in operation.

INTRODUCTION

The necessity to include the boats of coastal fisheries under supervision of the classification society stimulates consideration of the problem once more[1],[2],[3]. The problem comes back again of establishing some recommendations ensuring sufficient safety of open deck fishing boats, mostly from their stability point of view. Such criterion should be very simple taking into account only these boat characteristic dimensions which are easy to be measured on existing boats. The presented proposals can be useful also for designer to select such proper main dimensions of the boats at which fulfilment of the stability recommendations would be satisfied.

THE BASIS OF STABILITY CRITERION

Usually, the stability criteria are based on statistical data. Such data were used to propose the first version of the stability criteria for open deck fishing boats [4],[5],[6]. This work was carried out in Chair of Ship Hydromechanics , Technical University of Gdańsk, in 1986 , sponsored by the Polish Register of Shipping. The collection of statistical data concerning the boat main dimensions was quite rich due to the number of boats being in operation at that time. From another point of view the collection was rather incomplete because only five body lines of different size boats were included there. All necessary particular calculations can only be done with the use of body lines.

The number of fishing boats which are now in service decreased considerably in comparison with the records of 1986. The number of body lines increased by one only. It was the ZKR 1 boat built recently in the workshop of Ship Technology Chair, Technical University of Gdańsk.The small number of collected data which could be used for calculations and comparative analysis in this investigation was its great disadvantage.

Generally, it can be said that the traditional craftsmanship of the Polish coast fishing boats created a particular type of boats which in spite of different length have very similar ratios of the main dimensions as well as the shape of frame sections. From some time one can find new designs where steel or GRP laminate are only used instead of wood. In such modern designs boat shape can be different from the traditional one even when the designer takes the original boat as a prototype. This can be observed very clearly on the newest ZKR1 boat designed according to the traditional shape. The ratio of the maximum breadth B_m to the depth D is here quite different from that of the earlier mentioned boats. The B_m/D ratio values of the investigated boats presented in Tab. 1.

Tab. 1 The breadth - depth ratio of the investigated boats [1],[4]

Boat symbol	A	B	C	D	E	F	Mean value x	Stand. deviat of x : SDx
$x=\frac{B_m}{D}$	2,681	2,434	2,472	2,786	2,500	1.875	2,458	0,316

The boat F (ZKR1) is more sensitive to heel due to its smaller breadth than the other boats.

Nevertheless it seems that the above given data are sufficiently representative therefore the average value of the ratio can be taken as the basis of the general stability criterion for open deck fishing boats.

THE STABILITY CHARACTERISTICS OF EXISTING FISHING BOATS

It was shown [4] that the righting arm up to the heeling angle at which the boat side comes into water can be expressed by the formula:

$$G Z \approx G M \frac{2F_b}{B_m} \qquad (1)$$

where:

- GM - initial metacentric height
- F_b=D-d - freeboard at the lowest boat side point from water surface
- B_m - maximum breadth of the boat with side planking but no fender taken into account

This formula is the basis for expressing the righting arms. It is assumed that the permissible heeling angle is 15° or the inclination when the edge of the boat side comes into water if this angle is less than 15°. In Fig.1 the heeling mass versus boat displacement is presented.

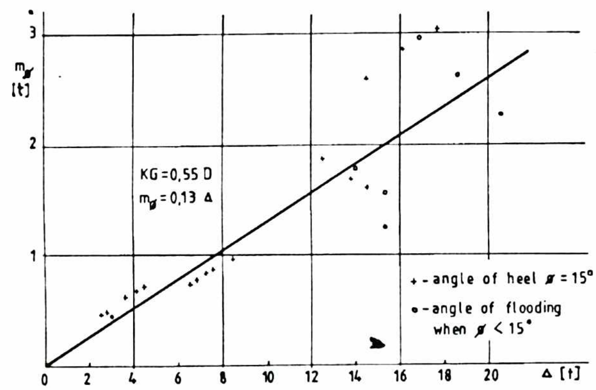

Fig. 1. The amount of heeling mass which inclines the boat to the permissible angle versus boat displacement

This is the mass which if located at boat side (the ordinate $y = B_m/2$) inclines the boat to the permissible angle. The displacement used for the A to E boats corresponds to their full load condition and also to their displacements 10% smaller or larger than that. For the boat F six displacements are used including overload condition.

For all boats the most probable ordinate of the centre of gravity, KG=0,55D, is assumed. Quite good correlation between the heeling mass and boat's displacement can be observed although all considered boats are of different size.

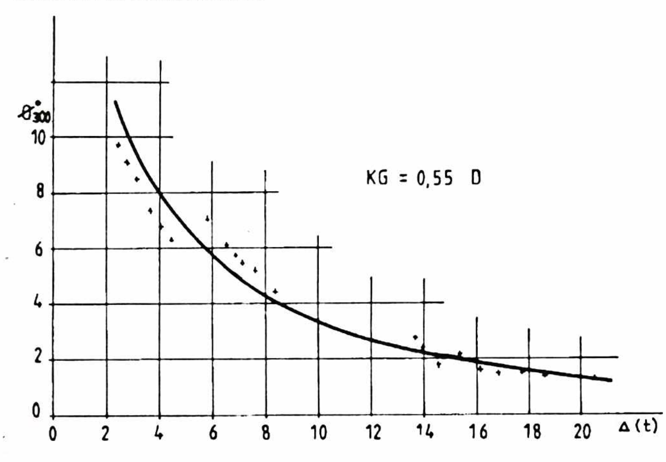

Fig. 2. The angle of heel versus boat's displacement when the mass of 300 kg is located at boat side

In Fig.2, the angle of heel versus boat's displacement is presented for the most probable ordinate of the centre of gravity and the boat load condition when the mass of 300 kg corresponding to the load of three fishermen together with fishing net is located just at boat's side.

ELABORATION OF THE STABILITY CRITERION

From the following equality of righting and heeling moments

$$\Delta \cdot G M \frac{2 F_b}{B_m} = m_\phi \frac{B_m}{2} \qquad (2)$$

the metacentric height can be calculated:

$$G M = \frac{1}{4} \frac{m_\phi}{\Delta} \frac{B_m^2}{F_b} \qquad (3)$$

If the ordinate of the centre of gravity is not larger than KG=0,55D it can be observed from Fig.1 that the mass m_Φ which inclines the boat to the permissible heeling angle is equal to:

$$m_\Phi = 0{,}13\ \Delta \qquad (4)$$

where: Δ - is boat displacement.

So the simple stability criterion for the required minimum metacentric height can be written as:

$$G M \geq 0{,}0325 \frac{B_m^2}{F_b} \qquad (5)$$

This inequality contains also the requirement for freeboard. From formula (5) the logical conclusion comes that if the boat freeboard decreases then the initial metacentric height has to be increased and this means that the boat must be more „stiff".

In consequence of the heeling angle limitation up to Φ = 15° it is necessary to put the F_b value not greater than:

$$F_b \leq 0{,}134\ B_m \qquad (6)$$

into the expression (5) even in the case if the actual freeboard $F_b > 0{,}134\ B_m$.

The proper safety level can be ensured by a suitable adjustment of the required metacentric height. If the metacentric height satisfying the following condition:

$$\text{GM} \geq 0{,}60 \text{ m} \qquad (7)$$

is assumed, the designer has no great freedom in selecting the boat breadth. The boat will satisfy the stability requirement when its maximum breadth

$$B_m \geq 2{,}47 \text{ m} \qquad (8)$$

It seems also that the specified value of freeboard is especially important for new boats intended to operate in rough waters. The freeboard should then satisfy the following condition where some safety margin is accounted for:

$$A = \frac{F_b}{B_m} \geq 0{,}15 \qquad (9)$$

The ratio A appears in the following relation of these boat main dimensions which influence its stability:

$$\frac{B_m}{D} = \frac{1}{d / B_m + A} \qquad (10)$$

where: D - the boat depth in the lowest point (bar keel not accounted for)

d - the boat draught (bar keel not accounted for)

THE APPROXIMATE EXPRESSION FOR METACENTRIC HEIGHT

From the stability criterion (5) the required initial metacentric height can be calculated, but for a given existing boat it is difficult to get an appropriate GM value without performing basic hydrostatic calculations and inclining test. However it is possible to assess the metacentric height in an approximate way when only some characteristic main dimensions are taken into account and if the ordinate of the centre of gravity is estimated with a sufficient accuracy.

The initial metacentric height may be expressed by three components:

$$GM = KB(d) + BM(d) - KG(D) \quad (11)$$

This can be approximated as:

$$GM = C_1 d + C_2 B^2/d - C_3 B \quad (12)$$

where: B - the waterplane maximum breadth (side planking accounted for)
C - constant factors.

Tab. 2. The form coefficients

Boat symbol/ hull form type	C_1	C_2
A	0,6532	0,1038
	0,6509	0,1011
	0,6452	0,0996
B	0,6490	0,1027
	0,6520	0,0988
	0,6526	0,0979
C	0,6183	0,0996
	0,6200	0,0971
	0,6195	0,0962
D	0,6107	0,1025
	0,6100	0,1002
	0,6047	0,0922
E/I	0,5676	0,0922
	0,5737	0,0916
	0,5651	0,0922
F/II	0,6487	0,1187
	0,6471	0,1106
	0,6455	0,1133
Mean value x	0,6241	0,1014
Standard deviation SDx	0,0305	0,0080

The form coefficients C_1 and C_2 of the considered boats are presented in Tab. 2.

It can be assumed that, for the fishing boats without deck or with partial deck only, the coefficient C_3 = 0,55, so the metacentric height for the whole boat population can be calculated taking into account the average values of C_1 and C_2 from Tab. 2. If the breadth B for a given draught d is unknown it can be assumed from statistical data that:

$$B \approx 0{,}95\ B_m \quad (13)$$

In order to increase the accuracy of calculation it was necessary to divide the boats into two hull form types, I and II, as it is given in Fig. 3.

It was thus possible to express the metacentric height of the boats with partially flat bottom near the keel as follows:

$$GM = 0{,}57\, d + 0{,}083 \frac{B_m^2}{d} - 0{,}55\, D \quad (14)$$

and of the boats with large rise of floor (15° ÷ 20°):

$$GM = 0{,}65\, d + 0{,}0957 \frac{B_m^2}{d} - 0{,}55\, D \quad (15)$$

DETERMINATION OF BOAT MAIN DIMENSIONS IN COMPLIANCE WITH THE STABILITY CRITERION

A boat is of sufficient stability at F_b/B_m = 0,15 if the metacentric height of the fully loaded boat is not smaller than that given by formulas (5) and (6) and :

- B = 0,95 B_m
- the coefficients C_1 and C_2 are assumed as the average values and C_3 = 0,55.

It means that the heeling angle of the boat will be smaller than the permissible angle 15° or the flooding angle, whichever is less, when a mass of 13% of the boat displace-ment is shifted onto the boat side and the boat is in comp-liance with following condition:

$$\frac{B_m}{d} \geq 3{,}26 \quad (16)$$

where: d - the maximum permissible draught (bar keel not accounted for).

If the boats are divided into two types according to their hull form which is reflected in (14) and (15) the safe breadth-draught ratio will be:

- for the boats with partially flat bottom near the keel

$$\frac{B_m}{d} \geq 3{,}85 \quad (17)$$

- and for the boats with large rise of floor

$$\frac{B_m}{d} \geq 3{,}05 \quad (18)$$

For an intermediate shape the minimum required B_m/d ratio will have also an intermediate value.

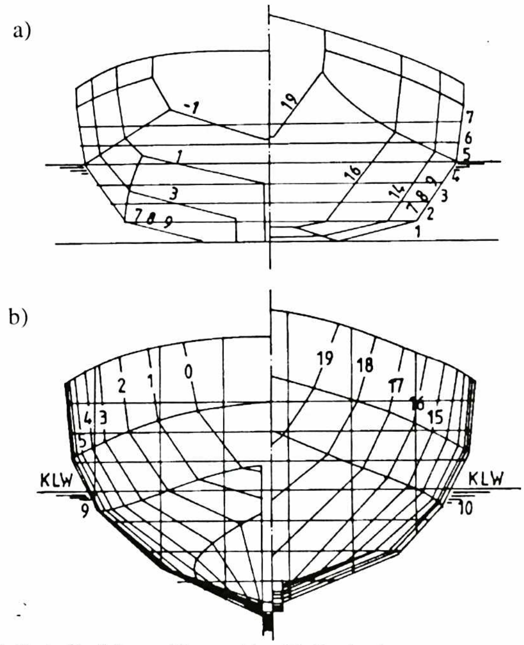

Fig. 3. Typical hull forms of the considered fishing boats
a) Type I - boat with partially flat bottom,
b) Type II - boat with large rise of floor

It can happen that the designer is able to assess the centre of gravity more accurately, and then coefficient C_3 would be different than the assumed value 0,55. The ratio $A=F_b/B_m$, which here is assumed 0,15, has also an influence on location of the centre of gravity. When values of these ratios are different from the assumed ones, the conditions (16),(17) and (18) are also different in that case. The minimum required B_m/d ratio calculated for two types of boats from (5) and (6) and also (14) or (15) for different values of C_3 = KG/D and A = F_b/B_m are presented in Tab. 3 and 4.

Tab. 3. Minimum required breadth - draught ratio in compliance with the stability criterion for the boats with partially flat bottom

F_b/B_m\KG/D	0,50	0,525	0,55	0,575	0,60
0,100	4,07	4,17	4,28	4,44	4,48
0,125	3,65	3,78	3,90	4,01	4,12
0,150	3,59	3,72	3,85	3,98	4,09
0,175	3,75	3,89	4,02	4,15	4,27
0,200	3,91	4,05	4,19	4,34	4,45
0,225	4,07	4,22	4,35	4,47	4,62
0,25	4,23	4,38	4,52	4,67	4,80

From Tab. 3 and 4 a safe value of the B_m/d ratio for a designed fishing boat can be determined. Having selected the boat's breadth with the condition (8) accounted for, the permissible draught d and the boat's depth D can be calculated from (10). In this way all boat's main dimensions which influence boat stability can be determined. The boat's length has no influence on its stability. The L/B_m ratio value ≈ 3 is empirically established from service experience.

Tab. 4. Minimum required breadth - draught ratio in compliance with the stability criterion for the boats with large rise of floor (15° ÷ 20°)

F_b/B_m\KG/D	0,50	0,525	0,55	0,575	0,60
0,100	3,47	3,58	3,69	3,79	3,89
0,125	2,81	2,96	3,10	3,22	3,34
0,150	2,75	2,91	3,05	3,19	3,32
0,175	2,91	3,07	3,21	3,35	3,48
0,200	3,07	3,23	3,37	3,51	3,64
0,225	3,22	3,38	3,53	3,68	3,81
0,250	3,38	3,54	3,69	3,83	3,97

THE SIMPLIFIED STABILITY ASSESSMENT

From the above mentioned remarks it can be stated that the fully loaded fishing boat without deck has sufficient stability when:

- the breadth - draught ratio is greater than that given in Tab. 3 or 4 respectively to boat's type. (For an intermediate boat's shape a corresponding intermediate value of the B_m/d ratio can be taken)
- the maximum breadth complies with the condition: $B_m \geq 2{,}47$ m.

When no reliable information about position of the centre of gravity is available the value $C_3 = 0{,}55$ can be assumed. The values given in Tab. 3 and 4 are the minimum required. When the boat breadth B_m is increased the ratio B_m/d becomes greater and stability of the boat increases.

From Fig.2 it can be observed that the boat in the design condition (boat completely outfitted but without any load) has sufficient stability when the expected number of crew members located at boat side induce such heeling angle that the minimum freeboard at the immersed side is not less than 0,05 m.

It is advisable that new boats in upright position comply with the following condition:

$$\frac{F_b}{B_m} \geq 0{,}15 \qquad (19)$$

FINAL REMARKS

The presented proposal is applicable to the fishing boats without deck or with partial deck, of the boat length from 5 to 12 m, outfitted with fixed engine. For boats operating in the open sea, in waves, up to 6 nautical miles from the coast line it is recommended that the boat's length (with stem and stern post not accounted for) should be not less than 7 m. Application of the sheer is also recommended. The fully loaded boat should have the freeboard at fore perpendicular not less than 0,55 m. The displacement of fishing boat operating in restricted waters should not be smaller than 1,6 t which corresponds to the boat length of about 5 m. The metacentric height of such small boats can be reduced up to 0,46 m which results in the breadth $B_m \geq 1{,}90$ m at $F_b/B_m \geq 0{,}15$.

The author would be grateful for any information which could enrich the bank of data obtained from hydrostatic calculations of the boats in question. The data would be used to better justify the presented recommendations or to correct them accordingly.

NOMENCLATURE

B - waterplane maximum breadth , with side planking accounted for, at draught d
B_μ - boat maximum breadth, with side planking but no fender accounted for
BM - metacentre above centre of buoyancy
Δ - boat depth in its lowest point, with bar keel not accounted for
d - boat draught, with bar keel not accounted for
F_β - boat freeboard
GM - initial metacentric height
GZ - righting arm
KB - centre of buoyancy above keel
KG - centre of gravity above keel
m_ϕ - mass which inclines a boat to the permissible angle, f
Δ - boat displacement

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Appraised by Wiesław Wełnicki, Assist.Prof.,D.Sc.,N.A.

Conferences

SAFE SHIP

International Conference in Gdańsk, 4 - 5 September 1996

Preparations for the Conference are passing a milestone.

The Organizing Committee is about to close the papers portfolio.

The already submitted papers fall into the following groups:

- ship structure strength (static and dynamic problems, calculation methods, experiment),
- ship hydrodynamics, buoyancy, manoeuvrability,
- onboard machinery,
- navigation systems,
- environment friendly design and materials,
- life saving appliances,
- the impact of rules and insurance on shipping safety.

The Conference program will be arranged respectively.

The Conference Participants and guests arriving on 3 September, will be invited to an ice-breaking party. A sightseeing tour to the City of Gdańsk will also be arranged.

The Conference will officially start in the morning, on 4 September, with a plenary session. After opening addresses three major papers will be presented. Then, after a lunch break 3 section meetings will take place. The first conference day will end with a party.

The second day program comprises 3 section meetings, a panel session and closing plenary session. In the meantime visits to one of the shipyards and a research center will be arranged.

A poster presentation and exhibition in the vicinity of conference rooms will accompany the conference sessions. Manufacturers of the products related to the conference subjects offered some video presentations too.

Visiting BALTEXPO FAIR is also worth to mention. All Conference Participants will receive the Baltexpo visitor's card.

The guests are expected from Australia, USA, Asia, West and Central Europe countries.

Everybody interested in the Conference subject is still kindly invited.

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