الأبحاث المنشورة (1968-2001)

فى مجال اتزان السفن

للأستاذ الدكتور محمد عبد الفتاح شامة

Published Papers (1968-2001)

on Ship Stability

by

Prof. Dr. M. A. Shama

1- Shama, M. A., (UK-1968) "A Method for Calculating Ship Stability Curves", Shipbuilding and Shipping Record, Aug.
2- Shama, M. A., (UK-1969) "A Computer Program for Ship Stability Curves", Shipbuilding and Shipping Record, May.
3- Shama, M. A., (UK-1975) "The Risk of Losing Stability", Shipping World and Ship, Oct.
4- Shama, M. A., (Germany-1976) "On the Probability of Ship Capsizing", Schiff und Hafen, Sept.
5- Shama, M. A., (Egypt-1989) "Safety Requirements for Nile Tourist Vessels", Seminar on Future of Nile Tourism in Egypt, (In Arabic), Alex., Eng. Journal, Vol.28, No.2, April.
6- Shama, M. A., (Egypt-1993) "Ship Stability Assessment, Criteria & Risk", AEJ, July.
7- Shama, M. A., and others, (Egypt-2001), "Intact Stability of SWATH Ships", AEJ, Vol. 40

A method for calculating ship stability curves

By M. A. Shama, B.Sc., Ph.D.*

A SIMPLE METHOD for calculating cross curves of stability is presented. The immersed volumes and their moments at different angles of inclination are calculated using areas and moments of areas of buttock planes. For each inclined waterline the co-ordinates of the centre of buoyancy are calculated from which the corresponding righting arm GZ is computed.

Ship stability is considered as one of the major seagoing properties of a ship and therefore should be carefully investigated and accurately calculated at small and large angles of inclination. At small angles of inclination, the righting arm GZ is assumed to be proportional to the angle of heel θ. At large angles of inclination, ship stability should only be represented by the statical stability curve, i.e. GZ and θ curve. This curve cannot be easily obtained at any specific loading condition unless corrections are made, in the course of calculations, to ensure equal volumes at each inclination. However, this curve is normally obtained from the cross curves of stability i.e. curves of GZ against displacement, at the desired loading condition.

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THE CROSS CURVES of stability can be determined by several methods such as the integrator method (the most common and straightforward method but the accuracy relies on human judgment and the accuracy of the instrument) and Barne's method. Alternative methods have been proposed by other investigators such as Reech, Leland, Blom and Benjamin as given in references [1] and [2], but it is believed that none of these latter methods can be of any practical application, moreover they cannot be easily programmed for an electronic computer. Another method, using waterplane areas and moments measured from the centre line to successive buttock lines, has been proposed by K. Hoppe [3]. The method comprises a graphical and mechanical procedure and assumes that an integrator is available. F. Taylor [4] used a different method which was mainly intended for a computer programme. The method cannot be easily employed in design office work using desk calculating machines. Further L. Kupras and W. Majewski [5] analysed the cross curves of stability of series 60 using regression analysis. They presented their method in the form of a computer programme and a series of graphs using non-dimensional coefficients. From the computer programme or these graphs, the statical stability curve can be determined for any ship form of the series 60, (with a proviso that the form characteristics should be within certain limits of the ship form). Camber and superstructures are not taken into account.

In this paper, a simple method for determining cross curves of stability using buttock plane areas and moments of areas is presented. The idea of using buttock lines has been used before by George Nicol [6]. His method is based on a graphical solution and also requires an integrator. However, the method described in this paper is presented in a mathematical form and therefore could be efficiently performed using desk calculating machines. Further, it could be integrated with the other routine ship calculations into a single computer programme. The main advantage of the method is that it dispenses completely with the integrator.

Although the method is simple and straightforward, it suffers from some disadvantages. These are mainly:

a. The terminations and intersections of the buttock lines are badly defined especially at the flat of side and on the bottom.
b. In vessels with a rise of floor, the lowest part of each buttock line is above the keel so that a separate lower appendage is required in the calculation of the areas and moments of areas.

However, when the ship form is represented mathematically these disadvantages will disappear and the method will prove valuable.

In the paper different types of ship shapes are considered, namely, a box shaped vessel (full flat of side buttock), a diamond shaped vessel (zero flat of side buttock) and a barge model. In addition, the method has also been applied to an oil tanker of 37,200 tons displacement.

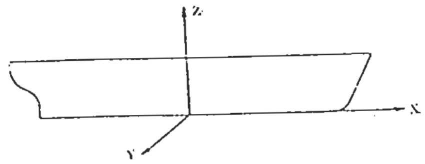
Ship stability curves

For the same ship, the righting arm GZ depends on the immersed volume of displacement (V) and the angle of inclination θ:

i.e. $GZ = f(V, \theta)$

The righting arm at any inclined waterline is generally calculated by computing the immersed volume (V) and the moment of this volume about the C.G. of the ship (M). The volume of displacement and its moments could be calculated by any of the following methods using the three reference perpendicular planes, X, Y, Z, see Fig. (1):—

Fig. 1 Three perpendicular reference planes, x, y, z



1. By integrating stations longitudinally:
   (a) $V = \int [\int y\,dz]\,dx$ and
   $M = \int [\int \frac{1}{2} y^2\,dz]\,dx$
   (b) $V = \int [\int z\,dy]\,dx$ and
   $M = \int [\int y\,z\,dy]\,dx$

2. By integrating buttock planes transversely:
   (a) $V = \int [\int x\,dz]\,dy$ and
   $M = \int [\int y\,x\,dz]\,dy$
   (b) $V = \int [\int z\,dx]\,dy$ and
   $M = \int [\int y\,z\,dx]\,dy$

3. By integrating water planes vertically:
   (a) $V = \int [\int x\,dy]\,dz$ and
   $M = \int [\int y\,x\,dy]\,dz$
   (b) $V = \int [\int y\,dx]\,dz$ and
   $M = \int [\int \frac{1}{2} y^2\,dx]\,dz$

The righting arm GZ is calculated as follows:

$$GZ = \frac{\text{Moment of volume of displacement about C.G.}}{\text{Volume of displacement}}$$

The generally accepted method is to calculate the moment of immersed volume about any arbitrary axis. The results are then corrected as follows:

$$(GZ)_{\text{actual}} = (GZ)_{\text{assumed}} \pm G\,G_1 \sin\theta$$

where: $G\,G_1$ = distance between the actual and assumed positions of the C.G. of the ship measured on the C.L. axis

The method described in this paper uses expression No. 2 (a) above i.e. the buttock planes are integrated transversely. For the buttock planes, area and moment of area curves about the base line, are drawn in the same way as Bonjean curves. The accuracy of the method depends on the accuracy of

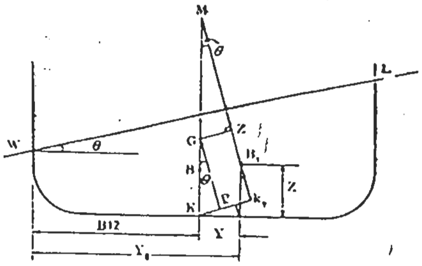


Fig. 6 Position of centre of buoyancy

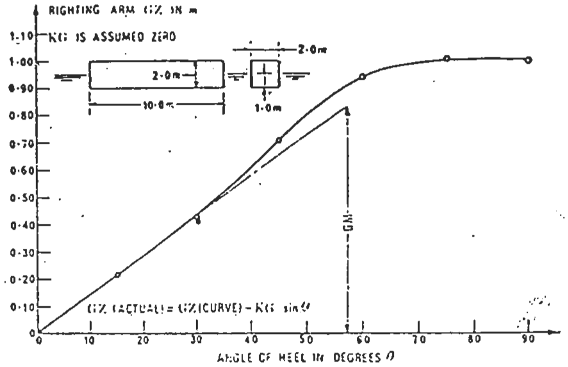


Fig. 7 Statical stability curve for a box-shaped vessel

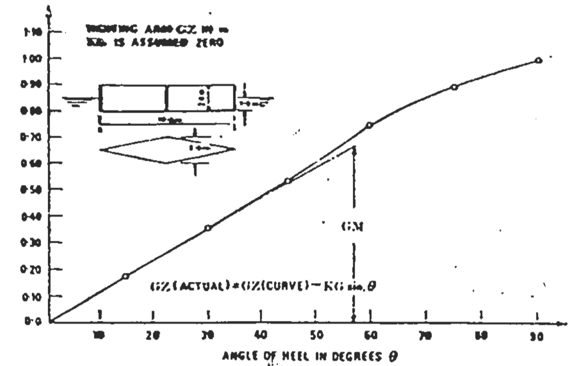


Fig. 8 Statical stability curve for a diamond-shaped vessel

b = buttock spacing = $\frac{B}{m}$

where B = moulded breadth and m = number of buttock lines.

A_j = buttock area for the jth buttock at the inclined waterline "W"

K_j = Simpson's multiplier

M_z = moment of volume about base line for the immersed volume V_w

M_j = moment of buttock area about base line for the jth buttock at inclined waterline "W"

M_Y = moment of volume about buttock No. 0, i.e. flat of side buttock on the emerged side, for the immersed volume V_w

j = buttock number = lever from buttock No. 0

p = buttock number which waterline "W" intersects at the base line, or the buttock at the half-breadth line on the emerged side, i.e. buttock No. 0

q = number of the buttock at the half-breadth line on the immersed side.

For simplicity of the calculation, four or five waterlines are taken for each angle of inclination as shown in fig. (4). From the point of view of added accuracy and also to suit the application of Simpson's integration rule it may be advisable to have a half buttock line near the bilge area.

6. Calculation of righting arm GZ

The righting arm GZ is calculated for each inclined waterline at each angle of inclination as follows, (see fig. 6).

$$GZ = KK_1 - KG \cdot \sin\theta$$

where $KK_1 = Y \cdot \cos\theta + Z \cdot \sin\theta$

$$Y = Y_B - \frac{B}{2}$$

$$Y_B = \frac{M_Y}{V_w}$$

$$Z = KB_1 = \frac{M_z}{V_w}$$

KB_1 = vertical position of the centre of buoyancy for waterline "W" inclined at angle θ

Hence GZ is given by:

$$GZ = \left(\frac{M_Y}{V_w} - \frac{B}{2}\right).\cos\theta + \frac{M_z}{V_w}\sin\theta - KG\sin\theta.$$

For different angles of inclination, the

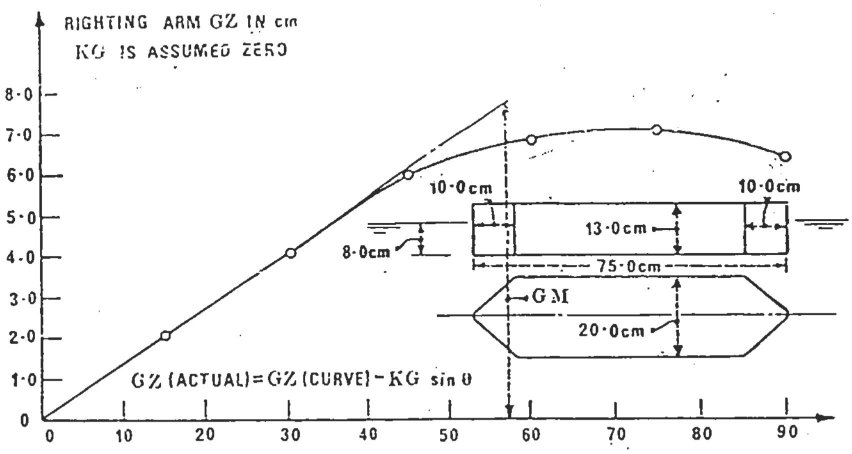


Fig. 9 Statical stability curve for a barge model

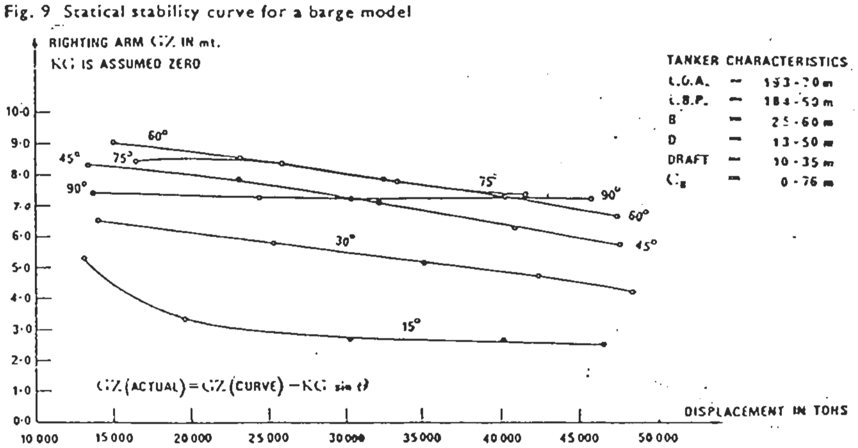


Fig. 10 Cross curves of stability for a tanker

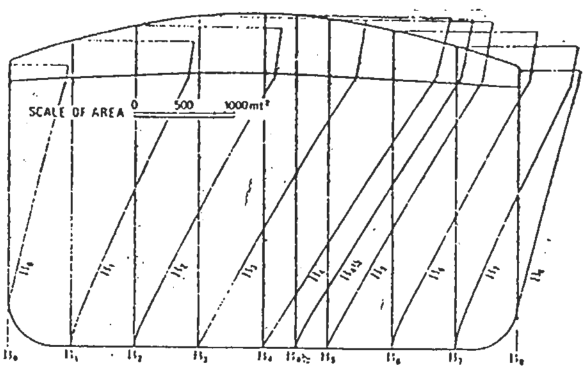


Fig. 11 Buttock area curves

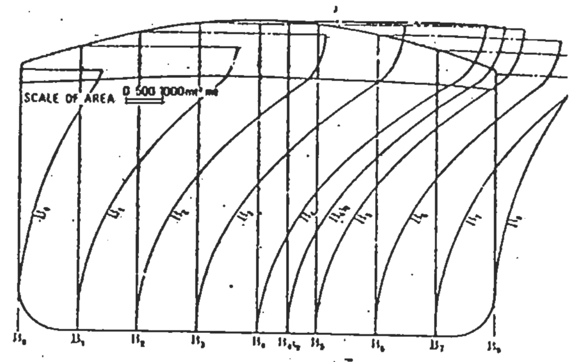


Fig. 12 Buttock moment of area curves for a tanker

righting arm GZ can be calculated at different displacements. Thus, the cross curves of stability can be obtained for any set of angles.

The method has been applied to different ship shapes and an oil tanker.

Figs. (7), (8) and (9) show the statical stability curves for a box shaped vessel, a diamond shaped vessel and a model barge. These curves are obtained from the cross curves of stability using the proposed method. Fig. (10) shows the cross curves of stability for an oil tanker. Figs. (11) and (12) show the buttock area and moment of area curves for this tanker.

Conclusions:

When the proposed method is used, it will be possible to perform all ship calculations (hydrostatics, stability, floodable length curve, launching . . . etc.) using lines plan and a desk calculating machine. Subsequently a computer programme can be developed to make all the routine ship calculations. This will greatly reduce the time required to design a ship.

Acknowledgements:

I would like to thank Prof. J. F. C. Conn and Mr. M. Livingstone of Glasgow University for encouraging and helping me to publish this paper and for supplying me with references [3] and [6]. My thanks are also due to my wife for her encouragement and typing. The author wishes also to thank Mr. A. Koura for tracing some of the drawings.

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