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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 computer programme for ship stability curves

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

SEVERAL methods for calculating ship stability curves have been proposed by different investigators but these methods are either based on the conventional tables of offsets, or require the lines plan. However, since cartesian co-ordinates are used for the definition of the hull shape, the accuracy of these methods suffer from the bad representation of the lower part of the ship (from the base line to the upper turn of bilge) and also the region of the uppermost continuous deck.

The method described in this paper is based on polar co-ordinates for calculating, for any inclined waterline, the immersed sectional areas and their moments about an assumed pole. The cross curves of stability are determined from the immersed volumes and their moments at a series of inclined waterlines. It should be realised that the idea of using polar co-ordinates has been used before in Barnes' method, for the calculation of the areas and moments of areas for the immersed and emerged wedges. However, Barnes' method is only used to calculate the statical stability curve for a ship at a certain displacement. The method becomes impractical if used for the calculation of cross curves of stability.

Although the mathematics involved is simple and straightforward, the proposed method will be very lengthy and tedius if performed on desk calculating machines. Consequently, it has been programmed, in Fortran, for the University IBM 1620 computer.

The accuracy of this method depends on the magnitude of the angular interval (as the angular interval decreases, the accuracy is improved and this will be on the expense of machine time in addition to increasing the required amount of data). This problem is solved partly for ships having parallel middle body and partly by taking the angle of inclination a multiple of the angular interval. Hence, for a ship having negligible parallel middle body and using 11 stations, about 130 offsets/draught are required (the corresponding machine time is about 6 minutes). On the other hand, for a ship having about 40% parallel middle body, about 90 offsets/draught are required (the corresponding machine time is less than 4 minutes).

Method of calculation

The righting arm GZ, for any inclined waterline, is computed from the immersed volume (V) and moment of immersed volume (M) about an assumed pole. The volume and its moment are calculated (for an inclined waterline WL) from the immersed sectional areas and their moments as follows:

1. Immersed sectional area:

$$A_j = C_1 \sum_{i=0}^{i=n} K_i r_{ji}^2 \quad i = 0,1,2 \quad \ldots 12$$

2. Moment of immersed sectional area about an assumed pole on the centreline of the ship:

$$KA_j = C_2 \sum_{i=0}^{i=n} K_i r_{ji}^3 \cdot \cos\theta_i$$

where:

A_j = immersed sectional area for the station number j, j = 0, 1, 2, ... 10.

r_{ji} = radial ordinate number i(i = 0,1,2 . . . 12) for station number j (see fig. 1).

$C_1 = \frac{\pi}{72}$ when the angular interval = 15° and Simpsons first rule is used

$C_2 = \frac{\pi}{108}$

K_i = Simpson's multipliers (1 4 2 4 . . . 1)

n = Number of ordinates = 0, 1, 2 . . . 12

θ_i = angle of inclination = $i\theta$, $\theta = 15°$

MA_j = moment of A_j about the assumed pole

The immersed volume of a ship for an inclined waterline WL at an angle θ_i is given by:

$$V_w = C_3 \sum_{j=0}^{j=m} K_j A_j \quad j = 0,1,2 \quad \ldots 10$$

The moment of this volume about the assumed pole is given by:

$$M_w = C_3 \sum_{j=0}^{j=m} K_j M A_j$$

where:

$C_3 = \frac{L}{30}$ and L = l.b.p.

K_j = Simpson's multipliers 1 4 2 4 . . . 1

m = Number of stations = 0, 1, 2, . . . 10

V_w = Immersed volume for an inclined waterline WL

M_w = Moment of V_w about the assumed pole

The righting arm GZ, for any inclined waterline WL, is calculated as follows, (see fig. 2):

$$GZ = KK_1 - KK_3$$
$$= d \sin\theta_i + X - KG \cdot \sin\theta_i$$
$$= (d - kG)\sin\theta_i - X$$

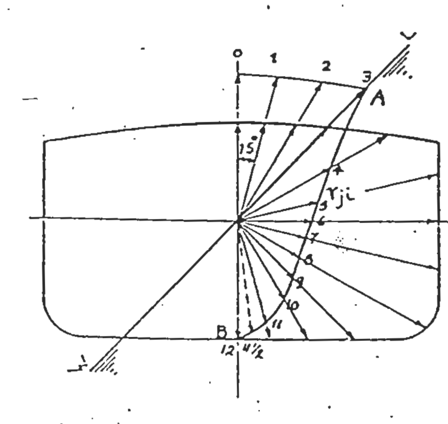

Fig. 1 Radial ordinates at 15° interval

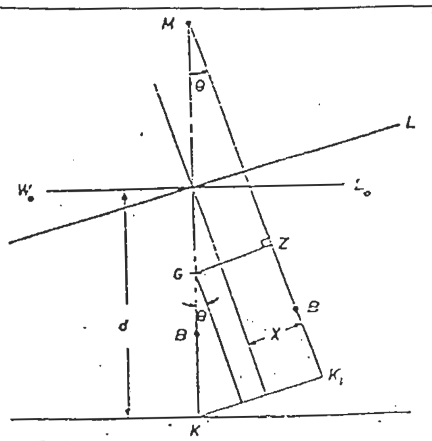

Fig. 2 The righting arm G2

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Fig. 3 Cross curves of stability for a square section vessel

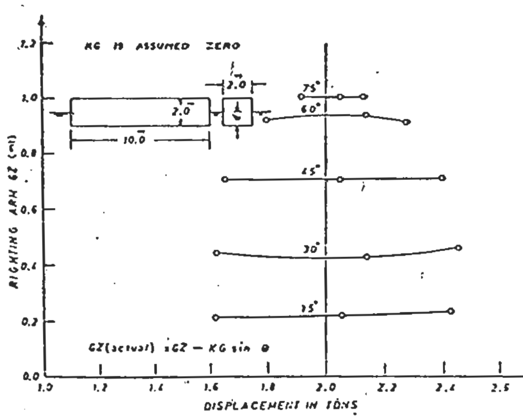
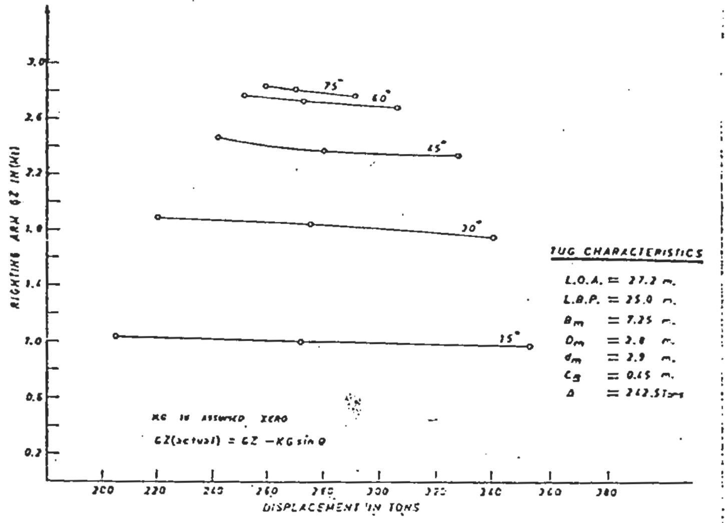


Fig. 4 Cross curves of stability for a harbour tug.



where:

θ_1 = angle of inclination = 15°, 30°, 45°, 60° or 75°

$$X = \frac{M_w}{V_w}$$

d = draught considered

This method of calculation is programmed for the University IBM 1620 computer, in Fortran, and the required data is given in Appendix I. The angular internal is 15° and the stability curves are calculated for the angles 15°, 30°, 45°, 60° and 75°.

Several cross curves of stability have been calculated for different ship shapes. The shapes considered are:

a. A square section vessel, see fig. 3
b. A harbour tug, see fig. 4
c. An oil tanker, see fig. 5

Apart from the simplicity of calculations, the method suffers from some disadvantages namely:—

a. The range of displacement for the angle of inclination of 75° is relatively small. However, this may be improved by increasing the range of draughts used, i.e., by increasing the distances between the poles.
b. The 90° inclination curve for GZ is not included in the cross curves of stability. It is believed, however, that this angle is not a vital characteristic of statical stability curves.
c. For the entrance and run, when the number of ordinates between the inclined waterline and ship centreline is an odd number, i.e., suitable for Simpson's first rule of integration, the stations areas are fairly accurate (this is the case of waterlines inclined at 0°, 30°, 60°, 90°). On the other hand, for even numbers of ordinates, i.e., for waterlines inclined at 15°, 45°, and 75°, a half ordinate at the ship centreline or at the 0° inclination waterline should be taken in order to eliminate the error resulting from the sharp corner at the intersection of the base line and centreline, see fig. 1.
d. The sharp corner between the deck and side, see fig. 1, may also cause an error in the magnitude of station area. This error may be positive or negative depending on whether a radial ordinate passes through the sharp corner or not. However, it is believed that, due to the presence of sheer in the deck, this type of error will sum up to a negligible amount when the immersed areas of stations are integrated along the ship length.

It should be noted that the above sources of errors appear only in the calculation of areas and volumes and disappear when calculating the righting arm GZ.

Conclusions

It is concluded that the accuracy of the method depends on the accuracy of the data (minor effect) and the magnitude of the angular interval (major effect). Using 15° angular interval gives comparable accuracy with other conventional methods. Better accuracy could be achieved with reduced angular interval. However, this improved accuracy will be on the expense of increased amount of data and machine time.

Fig. 5 Cross curves of stability for a tanker

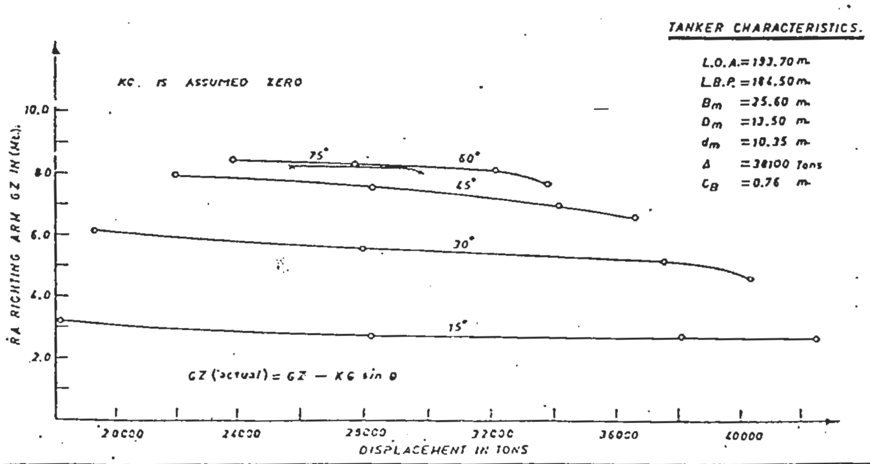


Fig. 6 Station boundaries for programme

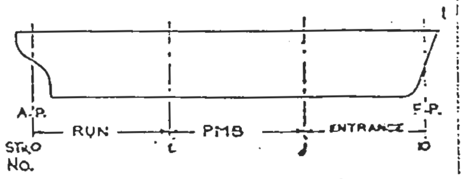
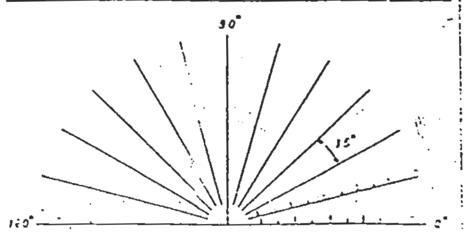


Fig. 7 A combined radial and linear scale



◀ Fig. 5 ▲ Fig. 6 ▼ Fig. 7

It is also concluded that this programme is very suitable for ship types which have a considerable rise of floor as the radial ordinates give better representation of the lower part of the ship and also for ships having a high percentage of parallel middle body. It is also expected that the method will give very accurate results when applied to submarines. Further, the method will be most useful when ship stability curves are required for trimmed conditions or among waves.

It is believed that the programme will be very powerful when the radial ordinates are generated from the ordinary table of offsets. This will greatly reduce the required amount of data and also will facilitate integrating the programme with other routine ship calculations programmes.

APPENDIX 1

Required data for the programme

In order to reduce the amount of data and machine time, the ship is divided into three major divisions, namely, "run", "P.M.B." and "entrance", as shown in fig. (6). Each division is treated separately in the programme. Areas and moments of areas for the run are calculated for the station number 0 to station number i, for the P.M.B. for station i and for the entrance, for station number (j + 1) to station number 10. The volume and moment of volume, for the P.M.B., are calculated using area and moment of area for station number i, for the run, using area and moment of area for station number 0 to station number i and for the entrance, using area and moment of area for station number j to station number 10, see fig. 8.

The required data are summarised as follows:

a. Radial ordinates for the run and entrance (13 ordinates are required/draught for each station). These data are read off from the body plan as shown in fig. 1. It is to be noted that the last station of the run is the first station of the P.M.B., see fig. 6.
b. Numbers of the fore and aft stations of P.M.B.
c. Number of draughts (up to 6 draughts).
d. Different draughts ($d_1, d_2 \ldots d_n$).
e. L.B.P. of ship.

A simple method for preparing the large amount of data can be achieved by using a radial scale as shown in fig. 7. The angular interval is 15° and the linear scale is 1/10, 1/20 . . . etc., depending on the scale of the body plan. This will greatly reduce the time required to read the radial ordinates from the body plan.

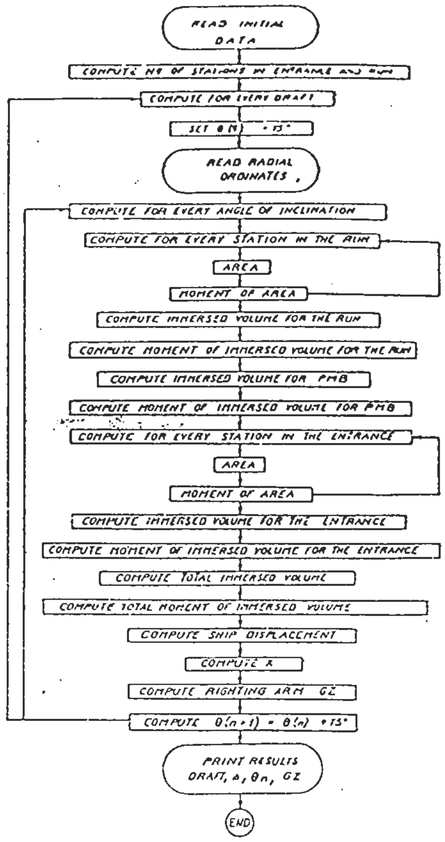


Fig. 8 Block diagram for cross curves of stability programme