By: MS **Date** 6th January 2016

Subject: Cross curves

1 CROSS CURVES

Using the hull defined data, the stability calculation performs a series of integrations with the ship heeled at any angle from –180 degrees to +180 degrees (upside down). The cross curve condition is defined as a series of explicit conditions at set angles of heel.

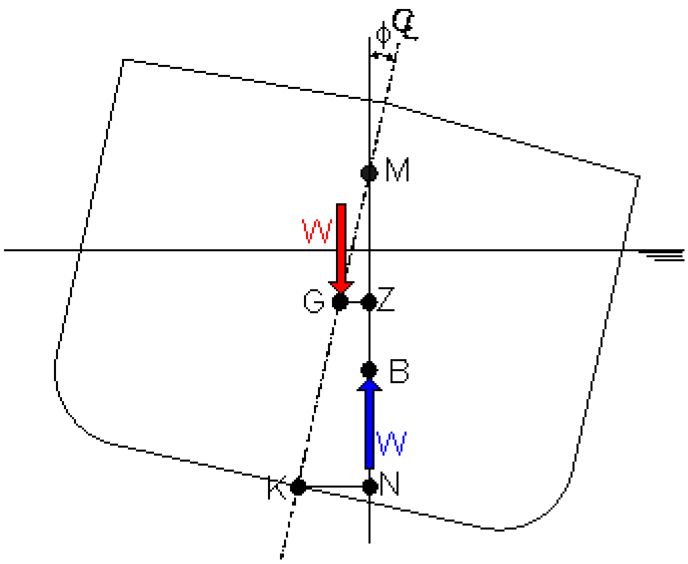
The options for entering a Cross Curve condition are as follows:

a. **Displacement, LCG**
Calculations at a range of displacements are performed for a range of LCGs. For each LCG value the stability value KN (see Figure 1) is calculated at all the set displacement values, forming a matrix of results.

b. **Displacement, Trim Over Marks**
Calculations at a range of displacements are performed for a range of trims. For each trim value the stability value KN is calculated at all the set displacement values, forming a matrix of results. The trim is over the length and relative to the aft and forward draught marks set in the Draught Marks Dialog.

c. **Draught at Mid Marks, Trim Over Marks**
Calculations at a range of draughts are performed for a range of trims. For each trim value the stability value KN is calculated at all the set draught values, forming a matrix of results. The draught is set at the Mid Marks longitudinal position and is above the Mid Marks Z position. The trim is over the length and relative to the aft and forward draught marks set in the Draught Marks Dialog.

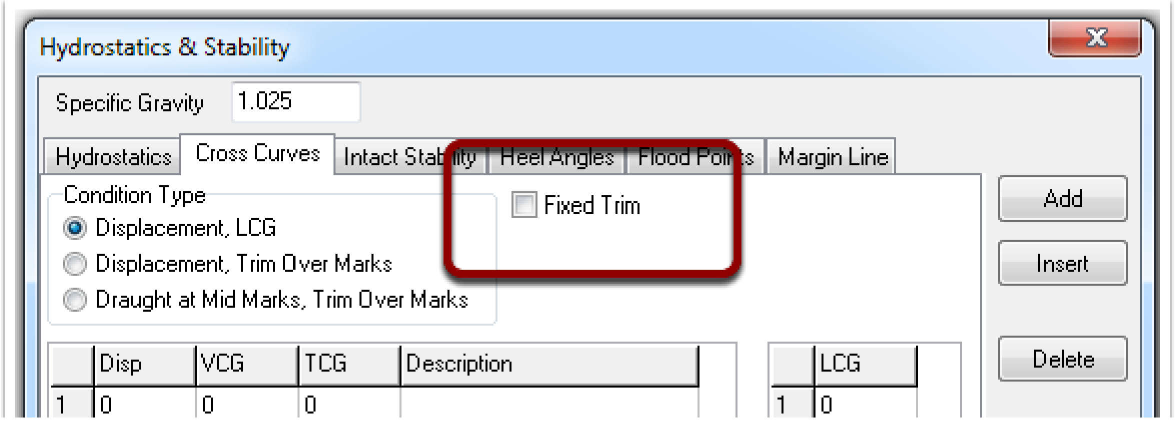
Figure 1 – definition of KN



Conditions for stability cross curves can be calculated for a fixed or free trim mode and produce tabulated results of cross curves displaying KN for a range of displacements and heel angles.

The ‘Fixed Trim’ option of Figure 2 is used to calculate the cross curve stability in a fixed trim mode such that the trim from upright does not alter when the vessel is heeled.

Figure 2 – Fixed trim option



2 WHAT IS THE PURPOSE OF THE VCG INPUT?

All cross curve condition types of Figure 2 require a VCG input. When the program performs a cross curve stability calculation, the input VCG is used to derive the vessel’s righting lever GZ at equilibrium. The calculated GZ is then combined with the heel angle and the set VCG to derive KN, using the formula

KN = GZ + VCG * SIN(heel angle).

The calculated cross curves are all referred to the centre of gravity of the vessel positioned at the keel (VCG=0), hence they are designated as KN curves in the cross curve results. When constructing a GZ curve from the cross curves a simple correction for the actual centre of gravity height gives the required result at that trim.

For a vessel fixed in trim the input centre of gravity height may be set to zero, and this will not affect the calculated KN values. For a vessel free to trim, however, an artificial decrease of the centre of gravity height to the keel will cause an error in the calculated trim value, and a corresponding error in the KN value and freeboard values. In particular, a vessel with the centre of gravity at the keel cannot trim as much as it would do if the centre of gravity was higher up, so the calculated values for KN and trim are merely approximations of the values obtained for that vessel with the centre of gravity at a realistic height.

It is strongly recommended, therefore, that realistic VCG values be input to cross curve calculations for vessels free to trim.

3 CROSS CURVES FOR CATAMARANS

Numerical instabilities should be expected when calculating cross curves for catamarans modelled without a bridge deck or superstructure. This is likely to occur at large heel angles and heavier displacements, normally when one hull is fully immersed, and results in a ‘Ship failed to converge’ or ‘Ship sunk’ message at one or more combinations of displacement and heel angle.

If the total thickness of bridge deck plus superstructure is zero or very small, heeled waterlines at large heel angles may only intercept the bridge deck, which would result in a zero or very small waterplane area (WPA).

Below is the algorithm used by HST for calculating KN in fixed trim mode:

1. The program reads in the displacement, trim and heel to calculate KN at. Assume these numbers are 60 t, 0 m and 60 deg respectively.
2. The roll centre is used as a first estimate of draught, and the corresponding displacement is calculated. Assume the latter is 50 t.
3. The program reduces the 10 t imbalance in displacement by increasing the draught.
4. A new, interim draught is calculated from 10 t / SG / WPA. Note that this is a very large jump in draught if WPA is very small.
5. The new calculated waterline may yield a WPA that causes a larger imbalance or lie outside the ship, hence the lack of convergence.

The four options below are recommended, in order of preference, to minimize the risk of convergence errors:

a. The KN curves presented in a stability book should cover a heel range representing realistic seagoing conditions of the intact vessel. Assuming the vessel is not intended to operate with a hull up in the air, KN curves at large heel angles should not be presented. Convergence issues are unlikely to occur at small heel angles.
b. Allow the vessel to trim freely for cross curve calculations. This is achieved with the 'Displacement, LCG' condition type. The 'Fixed Trim' option should be unchecked. Note that a realistic VCG should be set for each cross curve condition, as pointed out in Section 2.
c. If a specific combination of displacement and roll angle causes convergence issues, calculate the position of the heeled waterline at equilibrium and input the equilibrium draught in the Roll Centre edit box of the Ship Properties dialog. The roll centre is used as a first estimate of draught, so this will force the program to start iterating near the equilibrium waterline.
d. A watertight bridge deck and /or watertight superstructure should be modelled, this may alleviate but not necessarily resolve the issue.