

## ANNEX 6

### STABILITY OF HYDROFOIL CRAFT

The stability of these craft shall be considered in the hull-borne, transitional and foil-borne modes. The stability investigation shall also take into account the effects of external forces. The following procedures are outlined for guidance in dealing with stability.

*The term “hydrofoil craft” is defined in 1.4.31 of the Code.*

*The term “hull-borne mode” has the same meaning as “displacement mode” defined in 1.4.22 of the Code.*

*The term “transitional mode” is defined in 1.4.57 of the Code.*

*The term “foil-borne mode” has the same meaning as “non-displacement mode” defined in 1.4.38 of the Code.*

*As required by 2.3.1, the stability of hydrofoil craft shall be assessed under all permitted conditions of loading.*

#### 1 Surface-piercing hydrofoils

##### 1.1 Hull-borne mode

1.1.1 The stability shall be sufficient to satisfy the provisions of 2.3, 2.4 and 2.6 of this Code.

1.1.2 Heeling moment due to turning

The heeling moment developed during manoeuvring of the craft in the displacement mode may be derived from the following formula:

$$M_R = 0.196 \frac{V_o^2}{L} \cdot \Delta \cdot KG \quad (\text{kNm})$$

where:

$M_R$  = moment of heeling;

$V_o$  = speed of the craft in the turn (m/s);

$\Delta$  = displacement (t);

$L$  = length of the craft on the waterline (m);

$KG$  = height of the centre of gravity above keel (m).

This formula is applicable when the ratio of the radius of the turning circle to the length of the craft is 2 to 4.

### 1.1.3 Relationship between the capsizing moment and heeling moment to satisfy the weather criterion

The stability of a hydrofoil boat in the displacement mode can be checked for compliance with the weather criterion K as follows:

$$K = \frac{M_c}{M_v} \geq 1$$

where:

$M_c$  = minimum capsizing moment as determined when account is taken of rolling;

$M_v$  = dynamically applied heeling moment due to the wind pressure.

### 1.1.4 Heeling moment due to wind pressure

The heeling moment  $M_v$  shall be taken as constant during the whole range of heel angles and calculated by the following expression:

$$M_v = 0.001 P_v A_v Z \quad (\text{kNm})$$

where :

$$P_v = \text{wind pressure} = 750 (V_w / 26)^2 \text{ (N/m}^2\text{)}$$

$$A_v = \text{windage area including the projections of the lateral surfaces of the hull, superstructure and various structures above the waterline (m}^2\text{)}$$

$$Z = \text{windage area lever (m) = the vertical distance to the geometrical centre of the windage area from the waterline}$$

$$V_w = \text{the wind speed corresponding to the worst intended conditions (m/s).}$$

*The method of calculating wind heeling moment for hydrofoils has been amended from the 1994 HSC Code to be similar to that used in annexes 7 and 8 for other craft types, also taking into account the worst intended conditions.*

### 1.1.5 Evaluation of the minimum capsizing moment $M_c$ in the displacement mode

The minimum capsizing moment is determined from the static and dynamic stability curves taking rolling into account.

- .1 When the static stability curve is used,  $M_c$  is determined by equating the areas under the curves of the capsizing and righting moments (or levers) taking rolling into account, as indicated by figure 1, where  $\theta_z$  is the amplitude of roll and MK is a line drawn parallel to the abscissa axis such that the shaded areas  $S_1$  and  $S_2$  are equal.

$M_c = OM$ , if the scale of ordinates represents moments,

$M_c = OM \times \text{displacement}$ , if the scale of ordinates represents levers.

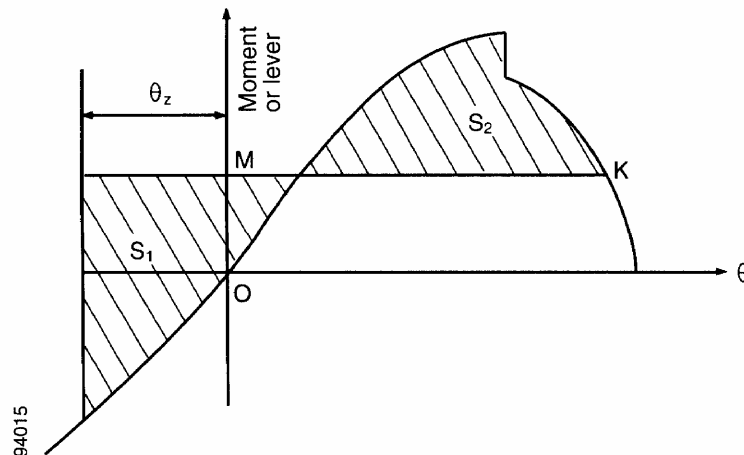


Figure 1 – Static stability curve

- .2 When the dynamic stability curve is used, first an auxiliary point A shall be determined. For this purpose the amplitude of heeling is plotted to the right along the abscissa axis and a point A' is found (see figure 2). A line AA' is drawn parallel to the abscissa axis equal to the double amplitude of heeling ( $AA' = 2\theta_z$ ) and the required auxiliary point A is found. A tangent AC to the dynamic stability curve is drawn. From the point A the line AB is drawn parallel to the abscissa axis and equal to 1 radian ( $57.3^\circ$ ). From the point B a perpendicular is drawn to intersect with the tangent in point E. The distance  $\overline{BE}$  is equal to the capsizing moment if measured along the ordinate axis of the dynamic stability curve. If, however, the dynamic stability levers are plotted along this axis,  $\overline{BE}$  is then the capsizing lever, and in this case the capsizing moment  $M_c$  is determined by multiplication of ordinate  $\overline{BE}$  (in metres) by the corresponding displacement in tonnes

$$M_c = 9.81 \Delta \overline{BE} \quad (\text{kNm})$$

- .3 The amplitude of rolling  $\theta_z$  is determined by means of model and full-scale tests in irregular seas as a maximum amplitude of rolling of 50 oscillations of a craft travelling at  $90^\circ$  to the wave direction in sea state for the worst design condition. If such data are lacking the amplitude is assumed to be equal to  $15^\circ$ .
- .4 The effectiveness of the stability curves shall be limited to the angle of flooding.

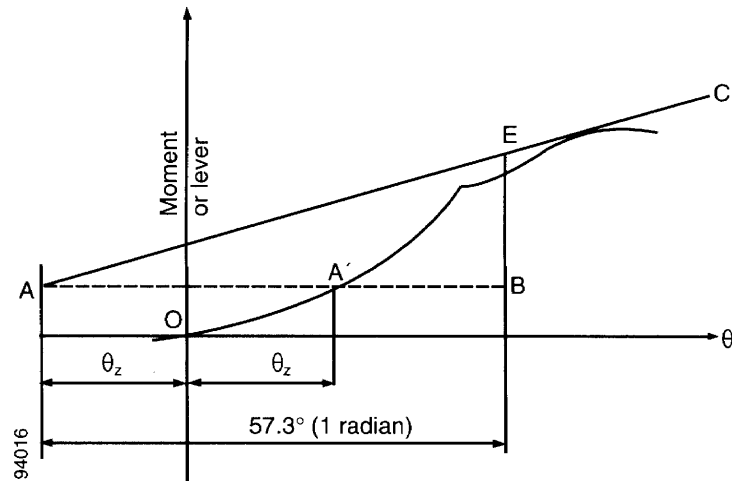


Figure 2 - Dynamic stability curve

## 1.2 Transitional and foil-borne modes

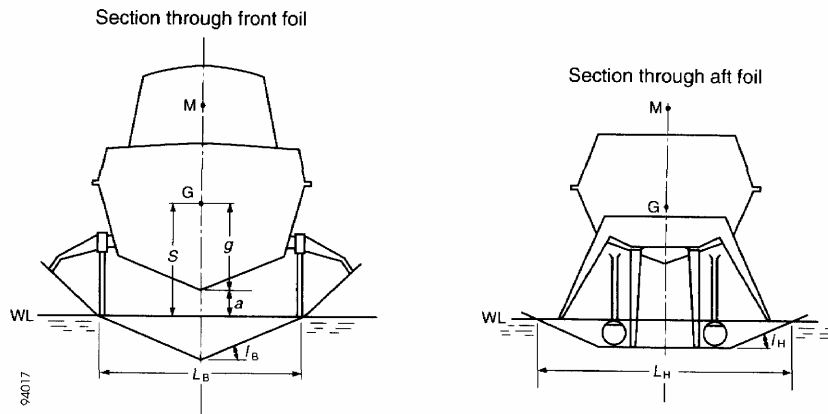
1.2.1 The stability shall satisfy the provisions of 2.4 and 2.5 of this Code.

1.2.2.1 The stability in the transitional and foil-borne modes shall be checked for all cases of loading for the intended service of the craft.

1.2.2.2 The stability in the transitional and foil-borne modes may be determined either by calculation or on the basis of data obtained from model experiments and shall be verified by full-scale tests by imposition of a series of known heeling moments by off-centre ballast weights, and recording the heeling angles produced by these moments. When taken in the hull-borne, take-off, steady foil-borne and settling to hull-borne modes, these results will provide an indication of the values of the stability in the various situations of the craft during the transitional condition.

1.2.2.3 The angle of heel in the foil-borne mode caused by the concentration of passengers at one side shall not exceed  $8^\circ$ . During the transitional mode the angle of heel due to the concentration of passengers on one side shall not exceed  $12^\circ$ . The concentration of passengers shall be determined by the Administration, having regard to the guidance given at annex 7 to this Code.

1.2.3 One of the possible methods of assessing foil-borne metacentric height (GM) in the design stage for a particular foil configuration is given in figure 3.



**Figure 3**

$$GM = n_B \left( \frac{L_B}{2 \tan I_B} - S \right) + n_H \left( \frac{L_H}{2 \tan I_H} - S \right)$$

where:

- $n_B$  = percentage of hydrofoil load borne by front foil
- $n_H$  = percentage of hydrofoil load borne by aft foil
- $L_B$  = clearance width of front foil
- $L_H$  = clearance width of aft foil
- $a$  = clearance between bottom of keel and water
- $g$  = height of centre of gravity above bottom of keel
- $I_B$  = angle at which front foil is inclined to horizontal
- $I_H$  = angle at which aft foil is inclined to horizontal
- $S$  = height of centre of gravity above water

## 2 Fully submerged hydrofoils

A "fully submerged foil" is defined in 2.1.3.2 of the Code.

### 2.1 Hull-borne mode

2.1.1 The stability in the hull-borne mode shall be sufficient to satisfy the provisions of 2.3 and 2.6 of this Code.

2.1.2 Paragraphs 1.1.2 to 1.1.5 of this annex are appropriate to this type of craft in the hull-borne mode.

### 2.2 Transitional mode

2.2.1 The stability shall be examined by the use of verified computer simulations to evaluate the craft's motions, behaviour and responses under the normal conditions and limits of operation and under the influence of any malfunction.

2.2.2 The stability conditions resulting from any potential failures in the systems or operational procedures during the transitional stage which could prove hazardous to the craft's watertight integrity and stability shall be examined.

### **2.3 Foil-borne mode**

The stability of the craft in the foil-borne mode shall be in compliance with the provisions of 2.4 of this Code. The provisions of paragraph 2.2 of this annex shall also apply.

2.4 Paragraphs 1.2.2.1, 1.2.2.2 and 1.2.2.3 of this annex shall be applied to this type of craft as appropriate and any computer simulations or design calculations shall be verified by full-scale tests.