TRANSVERSE STABILITY OF SURFACE PIERCING HYDROFOILS

Martin Grimm

The stability criteria presented in the IMCO Code of Safety for Dynamically Supported Craft, [1] now superseded by the International Maritime Association (IMO) High Speed Craft Code, provides an equation for assessing foilborne metacentric height (GM) of surface piercing hydrofoils in the design stage:

$$GM = n_B \left(\frac{L_B}{2Tan(I_B)} - S \right) +$$

$$n_H \left(\frac{L_H}{2Tan(I_H)} - S \right)$$

Where:

n_B, n_H = ratio of craft weight borne by front and aft foils respectively (as opposed to "percentage of weight" indicated in the IMO code)

L_B, L_H = width of front and aft foils respectively at foilborne waterline

I_B, I_H = angles at which the front and aft foils respectively are inclined to the horizontal where they cut the waterline

S = height of the centre of gravity above the foilborne waterline

The equation is derived based on the assumption that the lift distribution over the span is uniform and thus it does not take into account effects of spanwise variations in chord length or foil submergence depth. The equation is only intended to provide an indication of the stability of the foil at small heel angles.

An alternative method which addresses these limitations has been implemented in a short computer program. The

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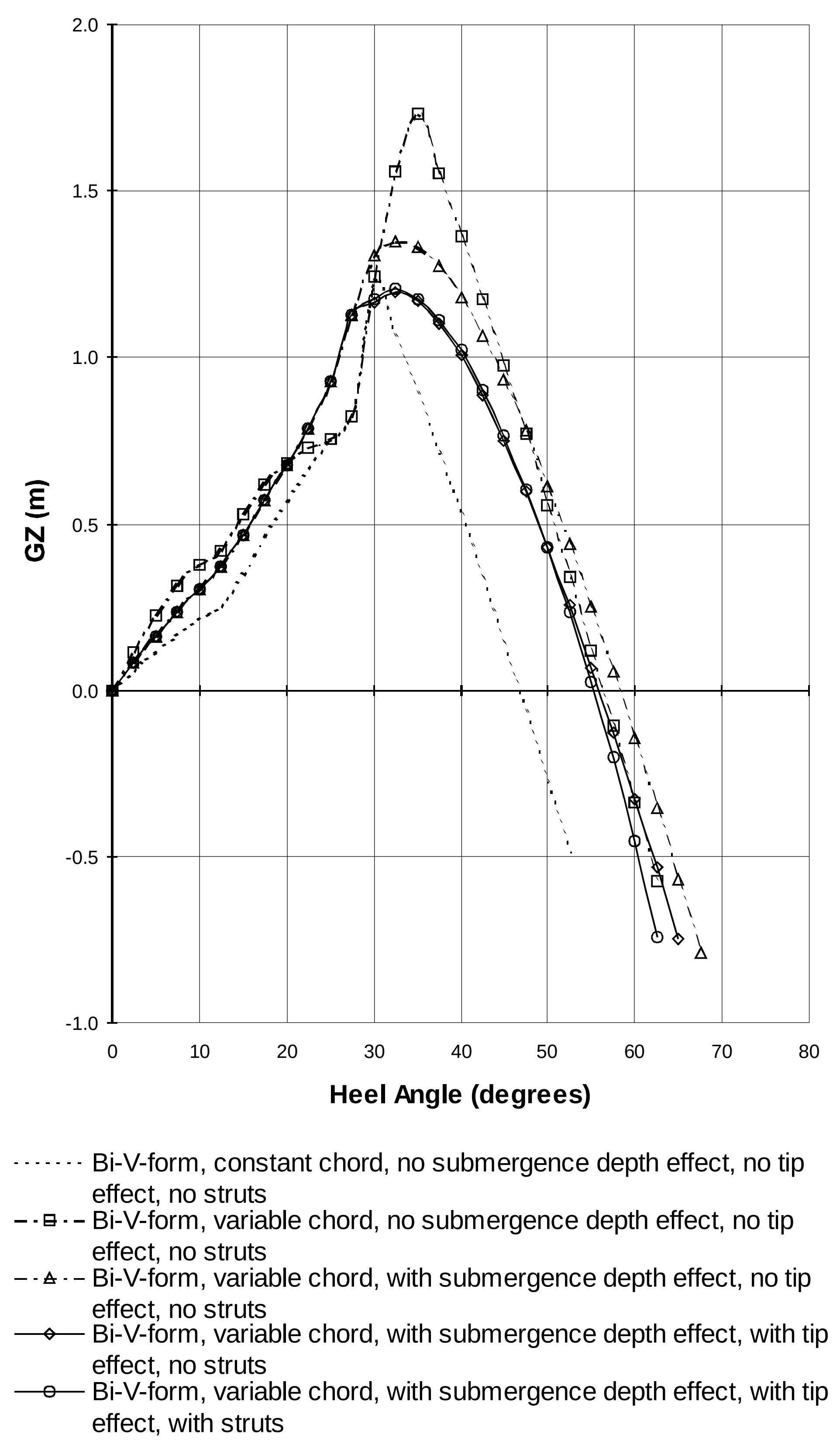

Transverse Stability, Figure 1
Righting Arm Curves For a Representative Surface-Piercing Bow Foil

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methodology used enables a flexible definition of the foil system geometry be it of a dihedral, ladder, or shallowly submerged configuration. While by no means rigorous, the program should be useful for preliminary design purposes. The main assumptions made in the program are that the lift generated at any spanwise element of the foil is:

- Proportional to its chord length,
- Related to the local submergence depth-to-chord ratio as proposed by Tsarev [2], and
- Is assumed to fall off elliptically towards the tips of submerged foils due to 3D flow.

To investigate the influence of various parameters on the righting arm, results from the program are presented for several variations of calculation method and foil geometry. The baseline geometry selected represents a bow foil typical of the RHS-140 hydrofoil series. These have narrow chord sections with a dihedral of ~17^{o} at their base increasing to a wider chord and a ~33^{o} dihedral angle at their outboard sections. This geometry will subsequently be referred to simply as a "Bi-V foil."

INFLUENCE ON CALCULATED TRANSVERSE STABILITY OF METHODOLOGY

The cases of foil definition and calculation method examined presented in Figure 1 include:

- Foil with constant chord and without submergence depth effect
- Foil with increases chord at tips but without submergence depth effect
- Foil with increases chord at tips and with submergence depth effect included
- Increases chord at tips, submergence depth effect and lift loss at tips included
- Increases chord at tips, submergence depth, lift loss at tips and strut lift all modeled

To aid in interpreting the results, the curves are presented for a single foil rather than a mixed pair. A representative vertical centre of gravity has also been included.

Although it is not possible to review the various effects in this brief presentation, it can be seen that the areas under the righting arm curves differ significantly with the assumptions made regarding the lift distribution.

INFLUENCE ON TRANSVERSE STABILITY OF FOIL GEOMETRY

The IMO guidance equation suggests that GM is only dependant on the shape of the foil at its foilborne waterline. To examine the influence of the submerged foil geometry on stability characteristics, the shape of the baseline foil was modified to obtain derivatives with variations below the design foilborne waterline but which remain unchanged about it. The two cases examined are:

- A foil system with a constant dihedral angle of about 33^{o} representative of the earlier Schertel-Sachsenberg hydrofoils; this geometry will be referred to as a "Pure-V"
- A foil system with a submerged horizontal foil element between the inclined outer foil elements which retain their dihedral angle of 33^{o}; this is representative of a stern foil on the RHS-140 series; this geometry will be referred to as a "_/ foil."

Figure 2 presents a comparison of the righting arm curves for the Pure-V, Bi-V and _/ foil geometries. Two calculation methods are applied to each of these three arrangements, one being the more approximate, the other being more refined. It can be seen that regardless of whether foil chord, submergence depth, or tip lift loss effects are considered, the Pure-V foil geometry exhibits the poorest stability characteristics of the three geometries examined, while the _/ foil has the greatest transverse stability.

ASSESSMENT OF OVERALL FOILBORNE STABILITY OF A HYDROFOIL CRAFT

The discussion to this point has been limited to considering a single foil system. If the interaction between the foils can reasonably be neglected, then the total righting lever can be calculated as follows:

$$GZ = (n_B)(KNB) + (n_H)(KN_H) - (KG)[\sin(\theta)]$$

where:

n_B , n_H = ratio of craft weight borne by front and aft foil

KN_B, KN_H =Righting lever of front and aft foil relative to craft baseline (m)

KG=Centre of Gravity above craft baseline (m)

θ =Heel angle (radians)

A more extensive assessment of the results and listing of the program and example input files is available from Martin Grimm, 9 Fishburn Street Red Hill, ACT 2603 Australia for those willing to examine this subject in further detail and report back on their findings.

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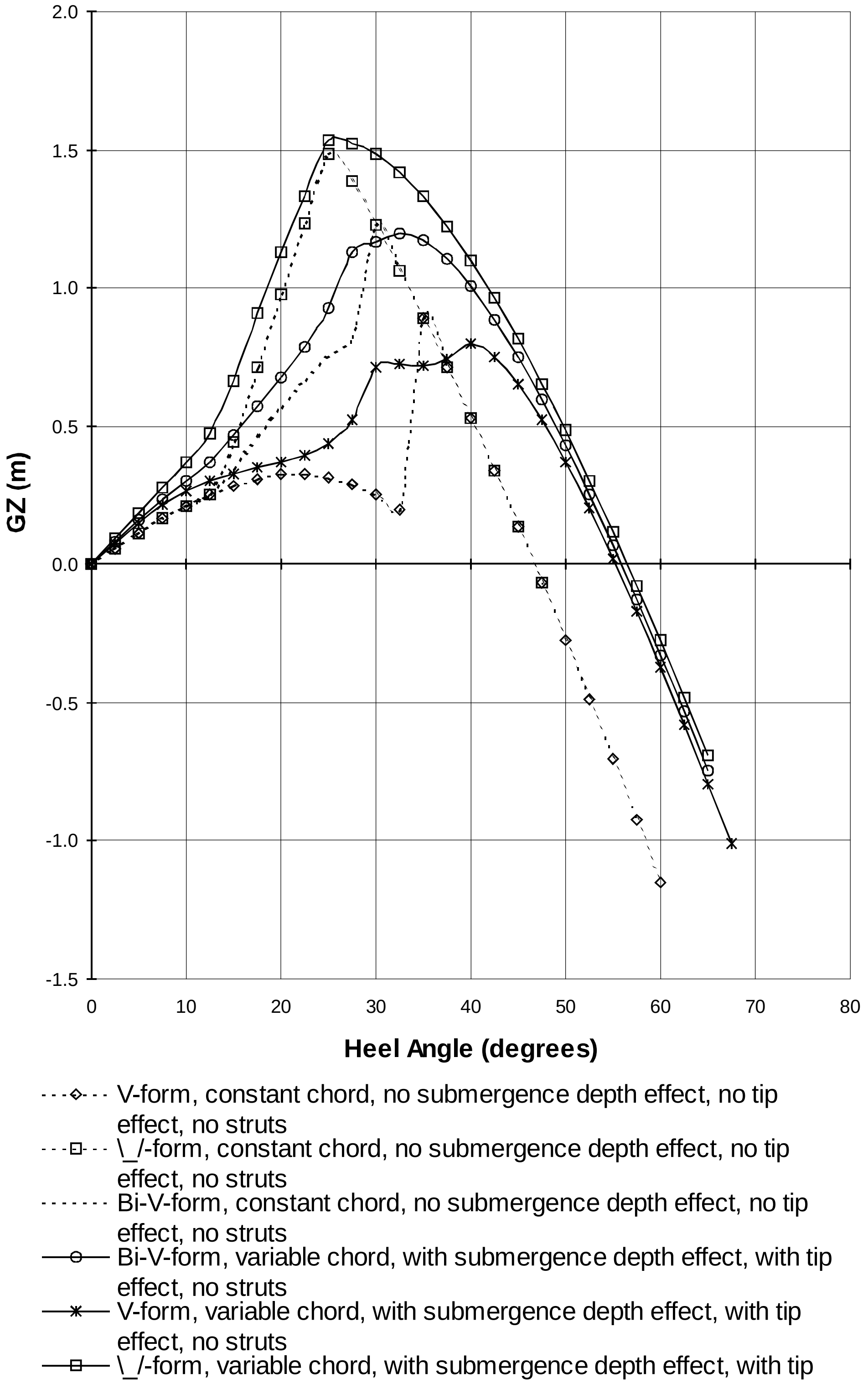

Transverse Stability, Figure 2
Righting Arm Curves For a Series of Surface-Piercing Foil Geometries

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REFERENCES

1.IMCO Code of Safety for Dynamically Supported Craft, 1978.

2.The Determination of the Stability of Vessels on Shallow-Submerged Foils Engineer B.A. Tsarev, Hovering Craft and Hydrofoil, Vol. 4, No. 1, Oct 1964.