Determination of Coefficient *K* for Prediction of Ship Squat

Following on from the June 2004 and November 2004 articles on ship squat by Dr C.B. Barrass, Mr P.J. Helmore proposes a regression equation for the calculation of the coefficient *K* for the prediction of the amount of squat.

Introduction

Barrass (2004b) presented a method for the prediction of ship squat when navigating in a rectangular channel or shallow water, and for the location of maximum squat. The amount of squat is given by:

$$\text{squat} = \frac{K C_B V^2}{100}$$

where

squat = loss of under-keel clearance (m)
C_B = block coefficient
V = ship speed (kn)
K = coefficient depending on (H/T) and (B/b)
H = water depth (m)
T = draft (m)
B = breadth of water (m)
b = beam (m)

The coefficient *K* was given by Barrass (2004b) in Figure 2, a two-dimensional plot for *H/T* values between 1.1 and 1.3 and *B/b* values between 3 and about 8.5. For values of *H/T* below 1.1, the conditions are dangerous, and above 1.3 squat should not be a problem. For values of *B/b* below 3 the channel is very narrow, and above 8.5 the water is simply shallow (and wide). The plot is easy to read, and a simple calculation using the above equation gives the predicted amount of squat; very useful when required.

Regression Analysis

The plot is at a small scale, and the most time-consuming part of the operation is in reading the value of *K*. The values of *K* appear to be continuous and well-behaved on the plot, and the author wondered if a surface could be fitted to the data so that the values of *K* could be determined from an equation. This would enable it to be programmed and, hence, the calculation to be performed more quickly in the design office.

Values of *B/b* were therefore lifted from the plot at five values of *H/T* for each value of the eleven values of *K*, a total of 55 data points. These data points were then run through a regression analysis using the mathematical package Matlab. A number of combinations of variables was tested, using polynomials of varying degrees. The best fit (with a correlation coefficient R^2 = 0.997) was obtained from the following equation, cubic in both *H/T* and *B/b* and without any cross products:

$$K = 5.0583915 - 0.2569568(H/T) - 1.0814519(B/b) - 0.4883445(H/T)^2 + 0.1306850(B/b)^2 + 0.1240496(H/T)^3 - 0.0057542(B/b)^3$$

Polynomials of lower and higher degrees, and inclusion of cross-products did not improve the goodness of fit.

Testing

The resulting equation was programmed, and then tested to see how well it would play back the original data. The maximum departure of *K* values given by this equation from the data lifted from the curves was ±3.2%, some of which may well have been due to the accuracy with which data could be lifted from the small-scale plot. However, 67% of the calculated values showed differences of less than 1% from the lifted data.

However, the ultimate test of any such regression equation is how well it can reproduce results which were not in the original data set. With this in mind, the equation was programmed, and compared with Barrass' (2004b) published results, as follows:

			Barrass Graph		Equation	
Worked example	*H/T*	*B/b*	*K*	squat (m)	*K*	squat (m)
1	1.25	3.55	1.752	0.36	1.767	0.37
2	1.10	5.60	1.374	0.24	1.382	0.24
3	1.15	7.25	1.120	0.45	1.142	0.46

It is doubtful whether the *K* values could be read from the published small-scale plot to four-significant-figure accuracy as shown; three significant figures would be reasonable. However, all values of squat calculated from the *K* equation are within 0.01 m of Barrass' values.

Barrass (2004a) also calculated the squat for *Queen Mary 2* for a given set of conditions, using a different approach and without using the *K* coefficient in his Worked Example 1. Applying the new equation to the same set of data gives *H/T* = 1.2, *B/b* = 6.098, from which *K* = 1.221 and squat = 1.00 m, which is the same value as obtained by Barrass.

Conclusion

A regression analysis of data lifted from the plot of Barrass' (2004b) *K* values has yielded an equation for *K* in terms of *H/T* and *B/b*. The equation enables values of *K* to be determined quickly and easily without having to refer to the plot. Values generated by the equation give results for squat which are close to published values.

References

Barrass, C.B. (2004a), Ship Squat and *Queen Mary 2, The Naval Architect,* Royal Institution of Naval Architects, London, June.
Barrass, C.B. (2004b), Squat Formula for Ships in Rivers, *The Naval Architect*, Royal Institution of Naval Architects, London, November.

Addendum

In a subsequent Letter to the Editor of *The Naval Architect*, published in the September 2005 issue, Dr Barrass gives his equation for the value of K as:

$$K = 6S + 0.4$$

where

S	= Blockage factor = $(bT)/(BH) = 1/(B/b)/(H/T)$
b	= beam (m)
T	= draft (m)
B	= breadth of water (m)
H	= water depth (m)

i.e. $$K = 6/(B/b)/(H/T) + 0.4$$

This is much simpler than the Helmore equation, gives the exact values quoted by Barrass in his examples (see previous page) and should be used.