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Subject: HST suite: the effect of centre of gravity height on stability calculations for a vessel free to trim

1 DISCUSSION

When calculating cross curves, the centre of gravity of the vessel is assumed to be at the keel and 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 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. This effect is shown by the small amount of data included in this report which were calculated for a proposed fishing vessel of conventional form. The principal dimensions of the vessel are as follows:

Length	Between Perpendiculars	20.42 m
Length	Overall	22.86 m
Beam	Moulded	6.4 m
Depth	Moulded	3.2 m
Depth	to Shelter Deck	5.8m

Free trimming statical stability calculations were carried out for initial trim values of 1m by the bow, 1m by the stern and level. Data are presented for light and loaded conditions. In each case the calculation was carried out both with the centre of gravity taken at the keel (Tables 1 to 3), and with an assumed centre of gravity height of 3m (Tables 4 to 6).

The values for KN in Tables 4 to 6 were derived from the GZ values using the formula

$$KN = GZ + VCG \sin \theta$$

where θ is the angle of heel.

Tables 4 to 6 therefore give correct values for KN and trim, and the values presented in Tables 1 to 3 are merely approximations. Comparison of Tables 1-3 and 4-6 reveals that for this particular vessel errors become considerable when trimmed by the stern, since the trim increases with increasing heel angle. Consider for example the case when Volume = 247.98m³ and initial trim = 1m (Tables 1b and 4b). With a heel angle of 45°, the error in KN is 1.3% and the error in trim is 0.41m, when VCG is assumed to be at the keel.

When the vessel is trimmed by the bow, as in the case where Volume = 115.25m³ and initial trim = -1m (Tables 2a and 5a), it first continues to trim by the bow, but as heel angle increases beyond 45° the direction of trim change is reversed. With a heel angle of 60° the trim is back to -0.98m and the results are correct in both tables. Discrepancies do occur however at other heel angles when the trim is somewhat different to its initial value.

Significant errors occur even in the case when the vessel is initially at level trim since this vessel experiences 2.35m of trim when heeling to 90°.

At this point the error in KN is 1% and the error in trim is 0.47m.

2 CONCLUSIONS

When calculating cross curves of stability using the free to trim method a representative VCG height should be used and the results corrected back to KN values for presentation.

When calculating cross curves using the free to trim method with the assumed VCG on the keel the errors in KN and freeboard are proportional to trim change and may become significant.

Table 1a Light load: GZ values with the centre of gravity at the keel, initial trim 1m by the stern

VCG = 0.00 m

Volume = 128.46 m³

LCB = -1.99 m

WL metres	TRIM metres	VCB metres	ANGLE OF HEEL degrees	GZ metres
2.00	1.00	1.38	0.00	0.00
2.01	0.97	1.41	10.00	0.65
2.05	0.87	1.51	20.00	1.25
2.11	0.80	1.65	30.00	1.77
2.24	0.83	1.92	45.00	2.37
2.37	1.01	2.32	60.00	2.88
2.53	1.49	2.80	75.00	3.21
2.73	2.01	3.19	90.00	3.19

Table 1b Heavy load: GZ values with the centre of gravity at the keel, initial trim 1m by the stern

VCG = 0.00 m

Volume = 247.98 m³

LCB = -2.10 m

WL metres	TRIM metres	VCB Metres	ANGLE OF HEEL degrees	GZ metres
3.00	0.99	1.97	0.00	0.00
3.05	1.17	1.99	10.00	0.55
3.14	1.47	2.04	20.00	1.07
3.25	1.77	2.12	30.00	1.57
3.41	2.22	2.34	45.00	2.27
3.60	2.68	2.59	60.00	2.78
3.83	3.07	2.82	75.00	3.04
4.07	3.41	3.05	90.00	3.05

Table 2a Light load: GZ values with the centre of gravity at the keel, initial trim 1m by the bow

VCG = 0.00 m

Volume = 115.25 m³

LCB = 0.53 m

WL metres	TRIM metres	VCB metres	ANGLE OF HEEL degrees	GZ metres
2.00	-1.00	1.29	0.00	0.00
2.01	-1.02	1.33	10.00	0.60
2.04	-1.07	1.42	20.00	1.18
2.08	-1.14	1.57	30.00	1.71
2.15	-1.16	1.90	45.00	2.40
2.25	-0.98	2.40	60.00	3.02
2.39	-0.69	2.99	75.00	3.44
2.57	-0.31	3.42	90.00	3.43

Table 2b Heavy load: GZ values with the centre of gravity at the keel, initial trim 1m by the bow

VCG = 0.00 m

Volume = 227.08 m³

LCB = -0.09 m

WL metres	TRIM metres	VCB metres	ANGLE OF HEEL degrees	GZ metres
3.00	-1.00	1.88	0.00	0.00
3.01	-1.00	1.90	10.00	0.60
3.03	-0.98	1.97	20.00	1.18
3.08	-0.89	2.09	30.00	1.73
3.17	-0.58	2.34	45.00	2.44
3.29	-0.19	2.64	60.00	2.96
3.50	0.17	2.92	75.00	3.20
3.78	0.55	3.22	90.00	3.22

Table 3 Heavy load: GZ values with the centre of gravity at the keel, level initial trim

VCG = 0.00 m

Volume = 236.70 m³

LCB = -1.13 m

WL metres	TRIM metres	VCB metres	ANGLE OF HEEL degrees	GZ metres
3.00	-0.00	1.90	0.00	0.00
3.01	0.01	1.92	10.00	0.60
3.07	0.12	1.99	20.00	1.15
3.15	0.33	2.08	30.00	1.66
3.27	0.72	2.32	45.00	2.36
3.43	1.15	2.60	60.00	2.87
3.65	1.52	2.87	75.00	3.12
3.91	1.88	3.12	90.00	3.13

Table 4a Light load: GZ values with the centre of gravity at 3m, initial trim 1m by the stern

VCG = 3.00 m

Volume = 128.46m³

LCB = -1.84 m

WL metres	TRIM metres	VCB metres	ANGLE OF HEEL degrees	GZ metres	KN metres
2.00	1.00	1.38	0.00	0.00	0.00
2.01	0.96	1.41	10.00	0.12	0.64
2.05	0.85	1.51	20.00	0.23	1.26
2.12	0.77	1.65	30.00	0.27	1.77
2.24	0.80	1.92	45.00	0.25	2.37
2.37	1.01	2.32	60.00	0.28	2.88
2.53	1.56	2.79	75.00	0.30	3.20
2.73	2.19	3.17	90.00	0.17	3.17

Table 4b Heavy load: GZ values with the centre of gravity at 3m, initial trim 1m by the stern

VCG = 3.00 m

Volume = 247.98 m³

LCB = -1.96 m

WL metres	TRIM metres	VCB metres	ANGLE OF HEEL degrees	GZ metres	KN metres
3.00	1.00	1.97	0.00	0.00	0.00
3.05	1.23	1.99	10.00	0.02	0.54
3.14	1.62	2.04	20.00	0.03	1.06
3.25	2.03	2.13	30.00	0.06	1.56
3.42	2.63	2.34	45.00	0.12	2.24
3.61	3.23	2.58	60.00	0.15	2.75
3.85	3.77	2.80	75.00	0.10	3.00
4.09	4.21	3.01	90.00	0.02	3.02

Table 5a Light load: GZ values with the centre of gravity at 3m, initial trim 1m by the bow

VCG = 3.00 m
 Volume = 115.24 m³
 LCB = 0.39 m

WL metres	TRIM metres	VCB metres	ANGLE OF HEEL degrees	GZ metres	KN metres
2.00	-1.01	1.29	0.00	0.00	0.00
2.01	-1.03	1.33	10.00	0.08	0.60
2.04	-1.09	1.42	20.00	0.15	1.18
2.08	-1.17	1.57	30.00	0.21	1.71
2.15	-1.18	1.90	45.00	0.28	2.40
2.25	-0.98	2.41	60.00	0.42	3.02
2.39	-0.66	2.99	75.00	0.54	3.44
2.57	-0.22	3.41	90.00	0.42	3.42

Table 5b Heavy load: GZ values with the centre of gravity at 3m, initial trim 1m by the bow

VCG = 3.00 m
 Volume = 227.08m³
 LCB = -0.23 m

WL metres	TRIM metres	VCB metres	ANGLE OF HEEL degrees	GZ metres	KN metres
3.00	-1.01	1.88	0.00	0.00	0.00
3.01	-1.01	1.90	10.00	0.08	0.60
3.03	-0.99	1.97	20.00	0.16	1.19
3.08	-0.87	2.09	30.00	0.23	1.73
3.17	-0.50	2.34	45.00	0.32	2.44
3.30	-0.04	2.63	60.00	0.35	2.95
3.51	0.40	2.91	75.00	0.29	3.19
3.79	0.85	3.20	90.00	0.20	3.20

Table 6 Heavy load: GZ values with the centre of gravity at 3m, level initial trim

VCG = 3.00 m
 Volume = 236.70 m³
 LCB = -1.13 m

WL metres	TRIM Metres	VCB metres	ANGLE OF HEEL degrees	GZ metres	KN metres
3.00	-0.00	1.90	0.00	0.00	0.00
3.01	0.01	1.92	10.00	0.08	0.60
3.07	0.14	1.99	20.00	0.12	1.15
3.14	0.40	2.08	30.00	0.16	1.66
3.28	0.89	2.32	45.00	0.23	2.35
3.44	1.43	2.59	60.00	0.26	2.85
3.67	1.90	2.85	75.00	0.20	3.10
3.92	2.35	3.10	90.00	0.10	3.10