COMPARISON OF MODEL PREDICTIONS AND SPEED TRIAL RESULTS FOR A GROUP OF 32′ WOODEN TRAWLERS

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Speed trial results of six 32' wooden stern trawlers built to the same design are analysed to determine the EHP ship – Froude number curves in each case and are compared with the model test results of the same design and for the corresponding displacement conditions.

INTRODUCTION

A knowledge of the relationship between the speed and the corresponding propulsion power requirement is important for the efficient utilisation of the installed power in a vessel. Small fishing trawlers generally work in the range of high Froude numbers and the above relationship becomes all the more important for the determination of the dimensions of a suitable propeller (fixed pitch) to satisfy the requirements of trawling conditions and varying service conditions. The speed – power relationships are normally predicted from the model test results. However, it is always necessary to compare the predictions with full scale speed trials with proto-types. This allows the determination of any correction factor necessary to improve the model predictions, which can be applied to subsequent vessels of the same type or even to the model results of similar vessels, to predict the actual performance more accurately. With this objective, speed trials were carried out with six 32′ l. o. a. wooden stern trawlers built to the same design and each covering a wide range of Froude number. The model test results for the hull were available for the different loading conditions. In the following, the speed trial results are analysed and compared with the model test results and the correlations are discussed.

MATERIALS AND METHODS

Measured mile speed trial trip data were collected for six 32′ wooden stern

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trawlers built to the same hull form. However, there were differences in the engines used for some of the vessels and in the displacement and trim in the trial condition. The vessels were fitted with 3 bladed bronze screw propellers of expanded area ratio generally between 0.45 to 0.50 and the blade geometry varied somewhat. The particulars of the vessels, the relevant details of the trial conditions and the propeller dimensions are shown in Table I.

The speed trials were conducted over measured distance of 3040 ft in the Mattancherry channel of Cochin harbour with ideal smooth water conditions. The measured distance was prominently marked by a pair of posts at each end, the lines of the pairs of posts being perpendicular to the marked course for the measured distance. The depth of water along the course was approximately 18 ft and the width of channel unrestricted.

Before the speed trials, the freeboards on both port and starboard sides at fore and aft ends and at midships were measured for plotting the floating water line on the lines plan to determine the trim, displacement and LWL length. A pair of up and down runs was taken for each engine r. p. m. During each run the engine r. p. m. were recorded several times to ensure that they were constant during the run. The wind velocity and directions were noted by a portable anemometer. Time for a run was clocked by a stop watch and the r. p. m. was measured by a tachometer on the centre point of the crank shaft at the forward end. In some cases, however the r. p. m. were measured by placing the tachometer wheel in contact with the propeller shaft and the shaft r. p. m. determined by comparing the diameter of the shaft and that of the tachometer wheel. The vessel speeds in the two directions of each pair of runs were calculated separately and the mean of these speeds was taken as the still water speed corresponding to that r. p. m. For each vessel five engine r. p. m. and corresponding speeds were obtained. Trials were attempted to be conducted mostly during slack tide. However, this was not always possible and tidal currents were present in most cases. The vessels were in water for about six months and since they were all copper sheathed, the fouling if any, was likely to be quite small.

It is known that the ground speed in calm water estimated from the mean speed of a single pair of runs in the opposite directions, in the presence of a tide current gradually varying with time, differs from the actual ground speed determined in calm water. The amount of correction is half the difference of the mean tide current speeds during each of the two runs of the pair and its sign depends on the direction of the first run (against or with tide) and whether the tide current speed is increasing or decreasing with time. An analysis was carried out for the corrections to the estimated speeds, as shown in Appendix II. In most cases the corrections were below 0 05 knots and were neglected. However, in four cases they ranged 0.08 to 0.15 knots and the corrections in these cases were applied.

The model resistance tests in calm water were carried out in the I. I. T. tank at Kharagpur and covered a Froude number range from 0 16 to 0.44 for six conditions e. g. three displacements each with even keel and one trim condition. The model was made to a scale of 1:5 and turbulence was stimulated by trip wire.

The analysis charts of the Troost standard 3 bladed series B 3.50 were used in the analysis for all the propellers. Strictly speaking, it was not correct to use the above standard series charts for all the propellers under study. But the differences were likely to be quite small considering the following.

Comparisons of the average η and δ values (average of the test data of several types of propellers varying in blade geometry and section shapes) given by Taylor and the corresponding values from the Troost series showed that the average values differed to some extent from the Troost series when the P/D and Bp combinations were near to the optimum efficiency line. Moreover, when the conditions of working were such that the P/D and Bp combinations were away from the optimum efficiency line, these differences rapidly decreased. This tended to show that when the conditions of working were not optimum, the finer details of blade geometry and section shapes did not affect the propeller constants and performances appreciably, as long as the number of blades, diameter and pitch were same and the blade area ratios were comparable. The propellers analysed here were working in conditions away from the optimum and so their performance could be analysed with the Troost series data without significant errors, even though their blade geometry and section shapes were not the same as given by Troost series.

An attempt was first made to analyse the trial data to derive the wake fractions. This actually required the measurements of the shaft horse power absorbed by the propeller. In the absence of such measurements, an assumption was made that under free running conditions and with full rated engine r. p. m. the propeller absorbed the corresponding full rated B. H. P. of the engine minus the transmission losses ie. the s. h. p. However, with this assumption about s. h. p., the derived wake fractions fluctuated widely showing the inadequacy of the assumption. So the analysis was discontinued and a Taylor wake fraction of 0.10 was assumed for all the vessels in the subsequent analysis.

The thrust horse power for the ship (T. H. P.) was derived from tne trial results with the help of the Troost B 3.50 propeller analysis diagrams and the corresponding ship EHP was obtained by assuming a thrust deduction fraction (t) of 0.1 and relative rotative efficiency 1.0 for all the cases. The method of derivation is shown in Appendix I.

The displacements of vessels 'A' and B' were 5.9 tons each and that of 'C' 6.5 tons. These three vessels were compared with model displacement condition of 6 tons. The EHP ship values for vessel 'C' were corrected to 6 tons in the ratio $\triangle^{2/3}$ Similarly, the displacements of vessels 'D', 'E' and 'F' were 8.0, 7.8 and 8.2 tons respectively and they were compared with model displacement condition of 8 tons. The EHP ship values for 'E' and 'F' were not corrected to 8 tons since the corrections were less than 1.5%.

RESULTS AND DISCUSSION:

Table I shows the details of the vessels and information regarding the trial condition.

Fig. I. shows the derived E H P ship curves for vessels 'A' 'B' and 'C' to a base of Froude No. (Fn) and compares them to the model test results for 6 tons displacement. Table II shows the percentage variation from the model results.

Fig. 2. shows the derived EHP ship curves for vessels 'D' 'E' and 'F' to a base of Froud No. (Fn) and are compared with the model test results for 8 tons displacement. Table III shows the percentage variation from the model results.

In the calculation of Froude No. the measured LWL lengths were used in all

TABLE I BOAT PARTICULARS

Boat	Displacement (tons)	Length water line LWL (ft)	Trim (ins)	Propeller Size (ins) Diameter	Pitch	Max. mean speed recorded Vs (knots)	Max. proppeller r. p. m.	Rated Engine b.h.p / r p m. red ratio	Estimated H. P. corresponding to max. obtained r. p. m.
A	5.9	27	4½ head	27	21.3	7.02	540	48/1500 3:1	19.25
B	5.9	27	5 head	27	21.3	6.35	467	48/1500 3:1	12
C	6.5	27	1.7 head	27.5	18.5	7.45	740	50/1500 2:1	46.7
D	8.0	29	2.8 head	35	24	6.72	383	50/1500 3:1	16.97
E	7.6	29′ 2¼″	1 stern	35	24	7.55	483	50/1500 3:1	42
F	8.2	29′ 5″	4 head	31	24	7.25	500	37.0/1500 3:1	32

cases. The model test results also followed the same method.

From Fig 1 it is seen that E H P ship curve for the vessel 'A' (4½″ head trim) practically coincides with the model test predictions over the whole range. The curve for 'B' (5″ head trim) is similar to 'A', but is consistently 39% above 'A' (Table II). The reason for the difference is not understood since the test condition for 'B' is identical with A'. But it is suspected that the stated propeller dimensions of 'B' are not accurate. The curve for vessel 'C' (1.7″ head trim) is also consistently above the curve 'A' except for the lowest speed. This is attributed to the fact that 'C' has a larger displacement in the test condition and the correction factor should be more than the assumed ratio $\triangle^{23}$. This is also seen if the model test results for 7 tons displacement are corrected in the ratio of $\triangle^{2/3}$ and are compared with the model test results for 6 tons displacement. The hump in the curve for 'C' may be due to mistake in recording r. p. m. and for comparison, the dotted line ignoring the hump is considered.

From Fig 2 it is seen that the curves are not so consistent as in Fig 1. EHP ship curve for E (2.8″ head trim) generally follows the model prediction at the higher speeds. The hollow in the curve for 'E' may be due to error in r. p. m. measurements and is ignored in the comparison. The curve 'D' (1″ stern trim) is above the model prediction and its trend does not follow the model predictions. The curve 'F' (4″ head trim) is consistently above the model prediction following a similar trend. The higher values specially at the higher speeds for 'F' are largely due to the effect of the 4″ head trim, compared to the stern trim of 'E'.

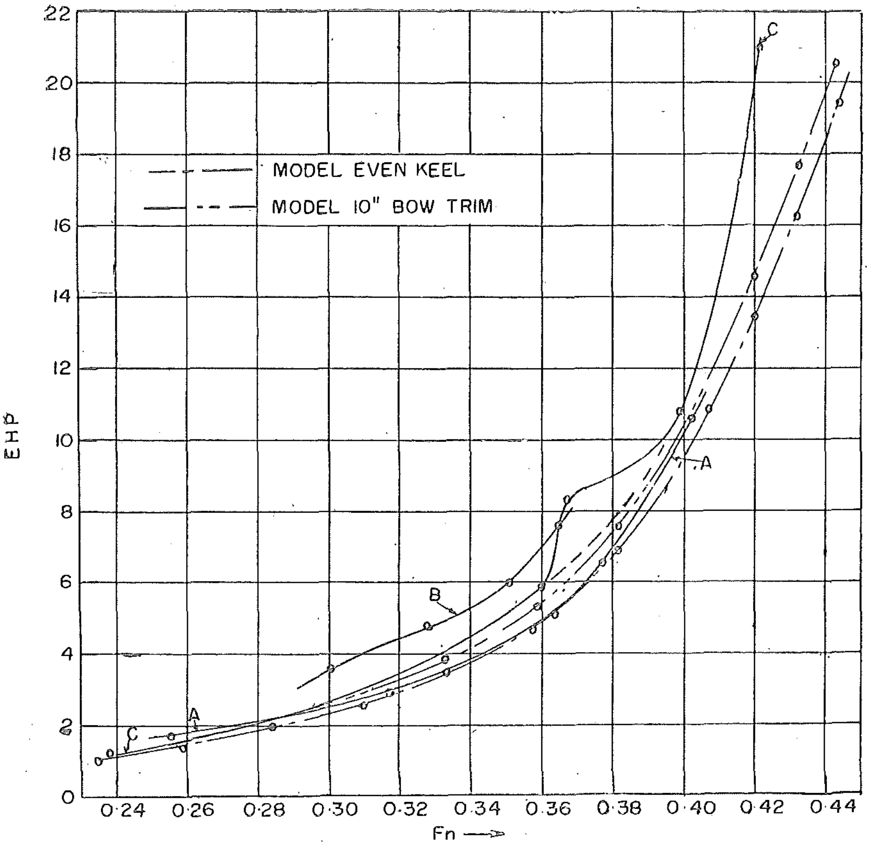

Fig. I. COMPARISON OF MODEL PREDICTION AND TRIAL EHP SHIP FOR 6 TONS DISPLACEMET

TABLE II CORRELATION BETWEEN TRIAL RESULTS AND MODEL PREDICTION FOR 6 TONS DISPLACEMENT CONDITION

Vessel	Displacement (tons)	Trim (ins.)	* Trial EHP ship/model EHP ship (10″ bow trim)								
			0.25	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.42
A	5.9	4.5	1.12	1.05	1 00	0.94	0.91	0.91	0.95	0.98	—
B	5.9	5 bow	—	—	1.39	1.33	1.26	1.30	—	—	—
C	6.5	1.5 bow	1.07	1.05	1.04	1.05	1.07	1.08	1.04	1.06	1.37

* Trial EHP ship are corrected to 6 tons displacement; but no trim corrections made. Model prediction corresponds to 6 tons displacement and 10″ bow trim.

TABLE III PERCENTAGE VARIATION FROM MODEL RESULTS

Vessel	Displacement (tons)	Trim (in)	* Trial EHP ship / Model EHP ship (even keel)							
			0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.42
D	8.0	2.8 bow	1.67	1.45	1.28	1.12	1.02	—	—	—
E	7.8	1.0 stern	—	—	1.23	1.24	1.09	0.92	0.88	0.98
F	8.2	4″ bow	—	1.23	1.33	1.32	1.27	1.15	1.47	—

* Trial EHP ship are not corrected to the common displacement of 8 tons, since the factor is small. No trim corrections are made. Model predictions correspond to 8 tons displacement and even keel condition.

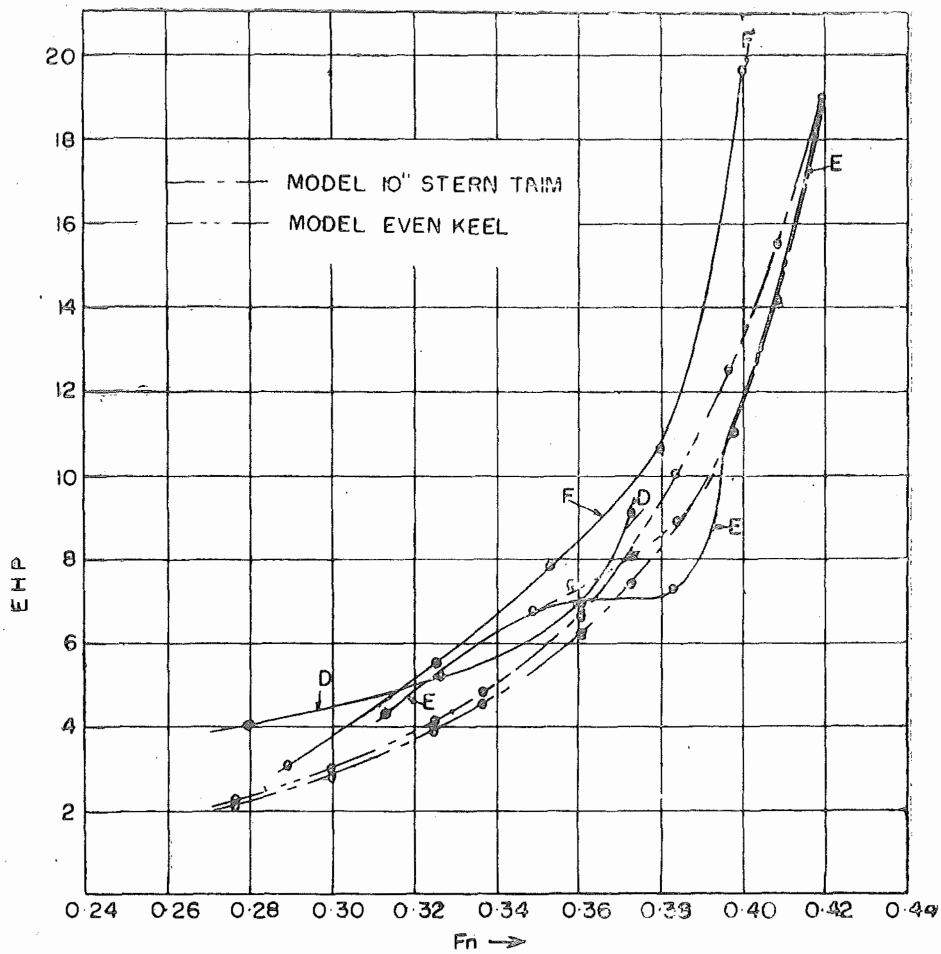

Fig 2 COMPARISON OF MODEL PREDICTION AND TRIAL EHP SHIP FOR 8 TONS DISPLACEMENT.

The results show that the assumptions in the method of analysis of wake fraction and thrust deduction are reasonable for predicting the full scale performance from the model results. Columns (8) and (9) of Table I show that only vessels 'C', 'E' and 'F' are utilising the installed power satisfactorily. The rather low r. p. m. for 'D' is due to the wrong adjustment of the throttle remote control.

Conclusions

For similar trim conditions and displacement, considering vessels A, E and F, an allowance of 10% on the model predictions (Tables II and III) is generally sufficient over the range Fn 0.34 to 0.40 which is of interest. However, in a small vessel of this type trim changes of 6″ can easily occur if a few persons move across half the length of the vessel. So an allowance of about 6″ adverse trim should normally be allowed in the estimation of power for any floating condition. The model results show that this allowance is approximately 5% for lower speeds upto Fn=0.34, thereafter increasing to about 10%. The EHP correction factor for the difference in displacement appears to be in the ratio of $\triangle^{1.5}$ and not $\triangle^{2/3}$ as assumed in the calculations. This is substantiated by the comparison of the model results for 6, 7 and 8 tons displacement condition.

The model results with the above

corrections can be used to predict the speed and engine loading satisfactorily by using the Troost B 3.50 data and assuming Taylor wake fraction 0.10, relative rotative efficiency 1.0 and thrust deduction 0.10. A direct measurement of the s. h. p. using a standard propeller is however felt necessary to determine the wake fractions and other related factors accurately over the whole speed range.

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APPENDIX I

Estimation of E H P ship from speed trial results

1) Vs_1 and corresponding N known from speed trials.
2) Vs (knot) = Vs_1 ± correction for tide effects (see Appendix II) Prop. r. p. m. = N/ reduction ratio.
3) Va (knot) = (1—wt) Vs, wt = 0.1 assumed.
4) Pitch (P) and diameter (D) from boat particulars.
5) $J = \frac{Ua}{nD}$
6) Kt & Kq against J from Troost B 3.50 series data.
7) $T = Kt.\ \rho\ n^2\ D^4$
8) THP ship $= \frac{Ua.T}{550}$
9) EHP_1 ship $= \frac{(1-t)}{(1-wt)}$ x THP ship, t = 0.1 and $\eta_r = 1.0$ assumed.
10. EHP ship $= \left(\frac{\triangle}{\triangle_1}\right)^{2/3}$ x EHP_1
11. $Q = K_q\ \rho\ n^2 D^5$
12. DHP ship $= \frac{2\ \pi\ nQ}{550}$

Where Vs = ship speed, knots (with corrections for tidal effects)
Va = speed of advance, knots.
Ua = speed of advance, ft. / sec.
wt = Taylor wake fraction
N = engine r. p. m.
n = propeller r. p. s.
P = Propeller pitch, ft.
D = Propeller diameter, ft.
t = thrust deduction factor
ηr = relative rotative efficiency
THP = thrust horse power
DHP = horse power absorbed by propeller.
EHP ship = effective horse power
ρ = density of sea water, 1.99 sec. ^{2} ft.$^{-4}$
$\triangle_1$ = ship dis-placement, tons
$\triangle$ = standard ship displacement to which results are converted
EHP ship = EHP_1 corrected to standard displacement ($\triangle$)

APPENDIX II

Correction to estimated speed for tidal effects

Let Vs be the actual ground speed in still water without any tidal current.

If the tidal current speed is 'a' and 'b' during the first and second runs, then the speeds recorded during the first and second runs are, if the first run is taken against the current.

$V_1 = Vs - a$
Mean speed recorded VS_1 = $V_s - \frac{1}{2}$ (a—b)
$V_2 = Vs + b$

and if the first run is with the current, then the recorded speeds are

$V_1 = V + a$
Mean speed recorded $V_{s1} = V_s$ +

$\frac{1}{2}$ (a—b)

$V_2 = V - b$

So the correction is $\frac{1}{2}$ (a—b) the sign depending on the direction of the first run. (a—b) is itself positive or negative depending on whether tide is increasing or decreasing with time. If a = b, the correction is nil.

During the speed trials the time intervals between the middle of the periods of the two runs of a pair were only 10 to 15 minutes and hence (a—b) is generally small. (Ref. Fig. 3).

If V1 and V2 are the speeds in two directions of pair of runs for same engine r. p. m. then

$V1 \backsim V2 = (a + b) = 2$ x the mean tide current which is $\frac{1}{2}$ (a + b)

Similarly, if V_3 V_4 ... V_9 and V_{10} are the successive pairs of runs (for different engine r. p. m.) $V_3 \backsim V_4$ $V_9 \backsim V_{10}$ give twice the mean tide current speed during the corresponding pair of runs. From these an approximate tide speed variation curve can be determined as shown in Fig. 3.

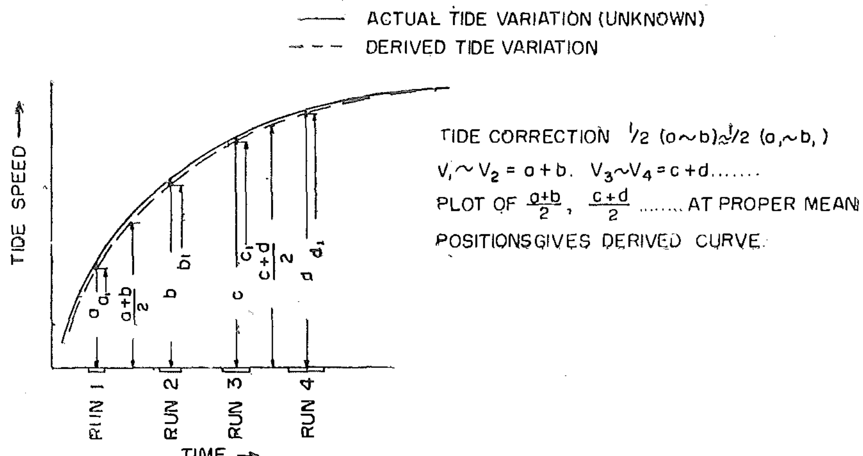

Fig. 3. TIDE SPEED CORRECTION TO ESTIMATED SHIP SPEED

From this curve, the difference (a—b) can be determined for a pair of runs and $\frac{1}{2}$ (a—b) with the appropriate sign gives the tide current correction to the estimated ground speed (V_{s1}).