On the Acceleration of a Naval Ship

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The March 2001 issue of MARENSA's newsletter, *Seaspace*, carried the following report:

> 'It is understood that HMAS *Brisbane* and HMAS *Anzac* competed recently in a sharp sprint over a three-mile course. *Anzac* had hoped that a quick engagement of gas turbine power would get them first to the finish line, but *Brisbane*'s 35-year-old boilers and steam turbines responded promptly to full throttle and the old girl showed she still had an unequalled turn of speed. It has been reported that she reached 32 knots on one minute from a standing start.'
> [Your Editor advises that, as the ship's commissioning engineer officer, he is not necessarily an impartial reporter.]

Having no experience with the acceleration of naval vessels, reaching 32 knots in one minute from a standing start sounded very quick to me. With interest aroused, I pulled out my copy of Lackenby's (1952) paper and did the following calculations to check whether the claim was reasonable:

Lackenby's equations for the time and distance to accelerate from rest to a given fraction *x* of the vessel's top speed, modified for use with SI units (Helmore 2000), are as follows:

$$t = \frac{MV}{H} F_t = \frac{(\Delta + \alpha) V^2 (1-t)}{222.6 P_E} F_s$$

$$s = \frac{MV^2}{H} F_s = \frac{(\Delta + \alpha) V^3 (1-t)}{13590 P_E} F_s$$

where
t = time to accelerate, min
s= distance to accelerate, n mile
F_t = time factor, from Lackenby's Fig. 7 or 8
F_s = space factor, from Lackenby's Fig. 9 or 10
M = mass of ship including mass of axially-entrained water, t
H = thrust of propeller(s) at speed V, kN
Δ = displacement, t
a = added mass of axially-entrained water, t
V = maximum speed, kn
v = intermediate speed
$x = v/V$
$(1-t)$ = thrust deduction factor
P_E = effective power at speed V, kW

F_t and F_s are dependent on the fractional speed x and the exponent n in the approximating resistance vs speed equation, $R_T = kv^n$, in the region of interest, i.e. just below the required speed v, as this is where the bulk of the acceleration time will be spent.

Not having all of the required information, we have to make some educated guesses:

Jane's (2000) gives the displacement as 3 370 tons standard and 4 618 tons loaded. Assume that the trial was done at the mean displacement of the two, i.e 3994 tons = 4 058 t.

Assume that $(\Delta + a) = 1.05\Delta$ for a high L/B vessel = 1.05×4 058 = 4 261 t.

Jane's gives the rated shaft power as 70 000 hp = 52 200 kW.

Jane's gives the maximum speed as >30 kn, which isn't much help. Assume, for the purposes of this calculation, that the speed at the rated shaft power is 34 kn. The volume Froude number at this speed is then 1.40.

Referring to Hadler and Hubble (1971) Fig 30, we find for twin screws, a volume Froude number of 1.40 and a shaft angle of 6° that $(1–t) = 0.99$ and increasing for lower shaft angles. This is not a Series 62 hullform, but the thrust deduction factor is likely to be of the right order for the flow around twin screws.

Assume a shaft transmission efficiency $\eta_S = 0.98$. The quasi-propulsive coefficient η_D is more difficult to estimate, but assuming high-efficiency propellers, we take $\eta_D = 0.65$. The effective power is then $P_E = \eta_S \eta_D P_E = 0.98 \times 0.65 \times 52\,200 = 33\,250$ kW.

At a final speed of 32 kn, the fractional speed $x = v/V = 32/34 = 0.94$.

Assume an exponent $n = 3$ for a low L/B, high-speed vessel.

Lackenby says that for steam turbine propulsion, the thrust characteristics lie between those for constant torque and constant power, but probably much closer to constant torque. We therefore use his Figures 7 to 10 with $n = 3$ and $x = 0.94$ to determine the time and space factors for both, and interpolate to give 80% towards constant torque:

Item	**Constant Torque**	**Constant Power**	**Turbine**
F_t	1.22	1.02	1.18
F_s	0.74	0.63	0.72

Hence:

$$t = \frac{4261 \times 34^2 \times 0.99}{222.6 \times 33250} \times 1.18 = 0.78 \text{ min}$$

$$s = \frac{4261 \times 34^3 \times 0.99}{13590 \times 33250} \times 0.72 = 0.26 \text{ n mile}$$

Most of the assumptions can be changed over quite a wide range (of the order of 20%) without changing the results by anywhere near the same amount; the maximum speed at the rated power of the turbines having the most effect. The conclusion remains the same: based on the assumptions above, HMAS *Brisbane* could reasonably accelerate to 32 kn in one minute from a standing start, and would get there in one-quarter of a nautical mile.

References

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