Forum

Assuring Punctual Arrival and Comcomitant Economy of Fuel

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1. INTRODUCTION. This paper presents a simple algebraic procedure which the marine navigator can use to assure punctual arrival and the maximum fuel economy compatible with this goal. The procedure is demonstrated by an example and its applications are discussed. Punctual arrival is assumed to be the primary objective and fuel economy is assumed to be the secondary and subordinate objective. In addition, the navigator is invited to contemplate certain navigational risks and their avoidance by the use of this procedure.

2. DEFINITION OF THE PUNCTUAL ARRIVAL/FUEL ECONOMY PROBLEM. Often, towards the end of a long sea passage, the navigator, who must enter his port of destination at a predetermined time, finds that at normal cruising speed he will arrive much sooner than is required or desirable if, as is often the case, he cannot enter the port immediately but must wait for daylight or some particular state of the current or height of the tide.

In this situation his options would appear to be:

(*a*) Continue at present speed and anchor off the port.

(*b*) Continue at present speed, arrive off the port, and manoeuvre about the entrance.

(*c*) Slow immediately to a speed equal to the quotient of the distance to go divided by the number of hours till the required arrival time.

The first choice is wasteful of fuel and other factors, such as the exposure of the anchorage, and the additional labour and expense required to anchor and get underway again, may well render it undesirable or impracticable.

The second option is even more wasteful of fuel, and the careful navigator will consider such factors as currents, depth of water, sea room, density of traffic and the availability and accuracy of fixes near the approaches to the port.

The third option is fuel-efficient and precludes the undesirable and dangerous consequences of the other two but, if punctual arrival is the paramount consideration, it may not be a wise choice for, depending on such variables as the accuracy of information and estimates of winds and currents to be encountered until arrival, and the accuracy and frequency of fixes available to the navigator, it may well result in late arrival.

3. CALCULATION TO ASSURE PUNCTUAL ARRIVAL. Another solution will require a small premium in fuel consumed over the third option, but will ensure punctual arrival.

If the navigator's vessel has a normal cruising speed of 15 knots, a minimum cruising speed of 9 knots, using heavy fuel, and if, twenty-four hours before his required arrival time, three hundred and twenty miles lie between his vessel and the sea buoy/arrival point, then a pair of simultaneous equations may be set up. It is assumed that the full

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cruising speed of 15 knots will be maintained for x hours and that the speed will then be reduced to 10 knots for the final y hours to the destination. We then have:

$$x+y = 24 \quad (1)$$
$$15x+10y = 320 \quad (2)$$

From (1)
$$-10x-10y = -240 \quad (3)$$

Adding (2) and (3)
$$5x = 80$$
$$x = 16 \text{ hours}$$
$$y = 8 \text{ hours}$$

If the navigator continues at full cruising speed for sixteen hours, he will be able to slow to 10 knots for eight hours with a large margin for error in the estimation of foul currents, unfavourable winds, or any other factor which might slow his speed of advance over the ground. This combination of speeds will require a modest premium in fuel consumption over the option of slowing immediately to a speed equal to the distance to go divided by the number of hours to the required arrival time.

If the vessel's consumption varies as the square of its speed and its consumption at the cruising speed of 15 knots is 0·1 tonne per nautical mile, then we may calculate the fuel premium. The constant speed required to cover the distance of 320 n.m. in 24 hours is given by:

$$320 \text{ n.m.}/24 \text{ hours} = 13{\cdot}3333 \text{ knots}$$

The consumption at 15 knots is:

$$0{\cdot}1 \text{ tonne} \times 240 \text{ n.m.} = 24{\cdot}0 \text{ tonnes}$$

The consumption at 10 knots is:

$$10{\cdot}0^2/15{\cdot}0^2 \times 0{\cdot}1 \text{ tonne} \times 80 \text{ n.m.} = \underline{3{\cdot}6 \text{ tonnes}}$$
$$27{\cdot}6 \text{ tonnes}$$

The consumption at constant 13·3 knots is:

$$13{\cdot}3333^2/15{\cdot}0^2 \times 0{\cdot}1 \text{ tonne} \times 320 \text{ n.m.} = \underline{25{\cdot}3 \text{ tonnes}}$$
$$\text{fuel consumption premium} = 2{\cdot}3 \text{ tonnes}$$

4. DISCUSSION. Use of the simultaneous equations to solve this problem does not provide a unique solution. Rather, the method should serve to provide initially a range of possible solutions from which the navigator will select that one which, in his judgement, best assures his punctual arrival; and then, as the vessel continues towards the sea buoy, a continuing refinement of such solutions. In the above example, any combination of speeds, such that the faster is between 15 knots and 13·4 knots and the lower is not less than 9 knots, can be substituted. Using speeds of 14·0 knots and 9·0 knots will result in a theoretical fuel consumption of 26·4 tonnes, a fuel premium of only 1·1 tonnes more than would be realized by slowing immeditely to 13·3 knots.

The conscientious navigator will evaluate his situation each time he obtains an accurate fix. The navigator so fortunate as to have available a continuous read-out of very frequent and reliable fixes may be satisfied simply to recalculate the speed necessary to reach the sea buoy at the appointed time. If he does, he should avail himself of the simultaneous equations to ensure that he has a sufficient margin of time and speed available. The provident navigator will use the simultaneous equations to assure his punctual arrival and achieve the greatest fuel economy possible in the circumstances.

KEY WORDS

1. Voyage planning. 2. Fuel management.