

Efficiency of Propellers

As described in section (Ddc), the propeller efficiency, η , is the fraction of the shaft energy that is used to propel the vehicle. Consider the simplest model of the propulsion of a boat using a propeller. Figure 1 is a diagram depicting the motion of a propeller blade in which we are now viewing the boat from vertically overhead. The velocity of the blade relative to the hull is denoted by V and this velocity is perpendicular to the direction of motion of the boat, U . The movement of the screw blade produces the lift, L , which propels the boat at its velocity, U , and is equal to the drag on the boat. Consequently is given by

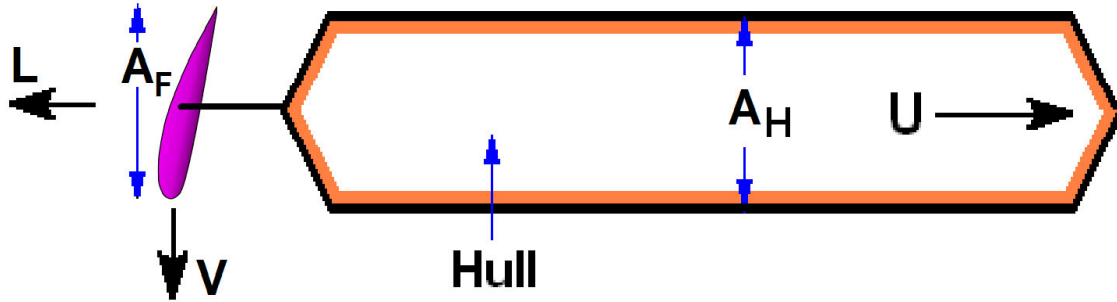


Figure 1: Schematic of a boat propelled by a screw propeller.

$$\frac{1}{2}\rho C_{LP}A_P V^2 = \frac{1}{2}\rho C_{DH}A_H U^2 \quad (\text{Mfd1})$$

where C_{LP} is the lift coefficient produced by the screw blade and A_P is the effective planform area of all the screw blades. Hence the velocity ratio V/U is given by

$$\frac{V}{U} = \left\{ \frac{C_{DH}A_H}{C_{LP}A_P} \right\}^{\frac{1}{2}} \quad (\text{Mfd2})$$

It is important to note that a well-chosen foil shape and angle of attack for the blade, will lead to a value of C_{LP} much larger than C_{DP} .

The rate of work done to move the screw blades through the water is

$$\frac{1}{2}\rho C_{DP}A_P V^3 \quad (\text{Mfd3})$$

where C_{DP} is the drag coefficient for the screw blade. Therefore, the propulsion efficiency is given by

$$\eta = \frac{\frac{1}{2}\rho C_{DH}A_H U^3}{\frac{1}{2}\rho C_{DH}A_H U^3 + \frac{1}{2}\rho C_{DP}A_P V^3} = \frac{1}{1 + \frac{V^3 C_{DP}A_P}{U^3 C_{DH}A_H}} \quad (\text{Mfd4})$$

and substituting for V/U this becomes

$$\eta = \frac{1}{1 + \left\{ \frac{C_{DH}A_H}{C_{LP}A_P} \right\}^{\frac{1}{2}} \frac{C_{DP}}{C_{LP}}} \quad (\text{Mfd5})$$

It is important to note the presence of the drag to lift ratio, C_{DP}/C_{LP} , in the denominator of equation (Mfd5). A well-designed screw blade profile and angle of attack can produce a drag to lift ratio much less

than unity which therefore will produce a much greater propulsion efficiency. This is another demonstration that a device which uses lift for propulsion (such as a propeller) has the potential for much greater efficiency than one that uses drag for propulsion (such as a paddle). This same property can be seen in many animal propulsion mechanisms and will be detailed in an earlier section.