Propulsion by Propellers

Selecting an Equivalent Multi-Blade Propeller

One of the quite often discussed mysteries among modelers is the selection of an equivalent 3 blade propeller for an existing 2 blade propeller. The following tips should help you in finding a good first start for a multi-blade propeller - some experiments will be necessary to find the "optimum" propeller.

In general each propeller blade needs a certain amount of power to be turned at a certain number of revolutions per minute and a given flight speed. Adding a third blade to a 2 blade propeller would increase the necessary power by 50%. Thus a different propeller diameter has to be selected for the same available power. If a family of propellers is available from a manufacturer, all propellers should have the same basic planform and twist distribution, which makes it possible to select a smaller multi-blade propeller as a replacement for a two bladed propeller.

Pitch

The propeller *pitch* is affected only by a negligible fraction, if we do not change to a very high number of blades. It could be reduced by 1 to 5 percent if more than 3 blades are used. Thus we can use the same pitch for the first selection. Therefore we note, that a change of the diameter *D* while keeping the pitch height *H* constant will also change the pitch/diameter ratio *H/D*.

Diameter

The diameter of a propeller, taken from a family of similar propellers, is very important for its power consumption. The power needed to turn a propeller depends directly on the number of blades and on the diameter by a power of 5. Scaling a propeller so that the diameter is doubled increases the necessary power to $2^5 = 32$.

Number of Blades

Changing the number of blades from B_1 to B_2 increases the power consumption from P_1 to

$$P_2 = P_1 \frac{B_2}{B_1}$$ if we use identical blades (having the same shape, diameter, and pitch).

A *scaling* of the complete propeller, so that the diameter changes from D_1 to D_2 changes the power needed to turn the propeller at the same number of rotations per minute to

$$P_2 = P_1 \left(\frac{D_2}{D_1}\right)^5$$

when the number of blades stays the same. Note that the scaling operation also changes the pitch height from H_1 to H_2 according to the geometric scaling law:

$$Scale = \frac{D_2}{D_1} = \frac{H_2}{H_1}.$$

Now, as we want to maintain the revolutions per minute and the forward speed we must also maintain the pitch H of the propeller: $H_2 = H_1$. Therefore the ratio *H/D* changes and we must account for this effect. Test results indicate that the power consumption is almost directly proportional to the ratio *H/D*. For a given diameter a doubling of the blade pitch results in twice the power consumption:

$$P_2 = P_1 \cdot \frac{\left(\frac{H}{D}\right)_2}{\left(\frac{H}{D}\right)_1} .$$

Putting both trends together (for propellers of the same power consumption) and solving for the new propeller diameter D_2 finally leads to the formula

$$D_2 = D_1 \cdot \left(\frac{B_1}{B_1}\right)^{1/4} .$$

Some Examples:

Switching from a two bladed to a three bladed propeller corresponds to a new diameter of

$$D_3 = D_2 \cdot \left(\frac{2}{3}\right)^{1/4} = D_2 \cdot 0.904 .$$

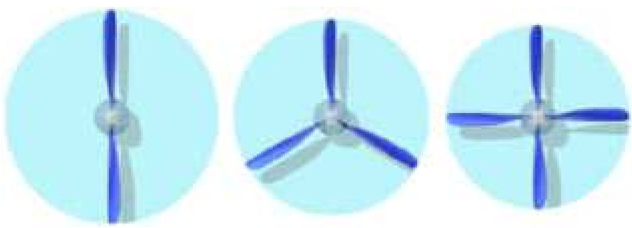
So we could replace a 2 bladed 12 x 10 inch model aircraft propeller by a 10.8 x 10 inch three bladed propeller - if we can find one; the pitch *H* is 10 inches in both cases.

Switching to a four bladed propeller instead requires a reduced propeller diameter of

$$D_3 = D_2 \cdot \left(\frac{2}{4}\right)^{1/4} = D_2 \cdot 0.840 .$$

Now the replacement propeller for our 2 bladed 12 x 10 inch model aircraft propeller would be a 10 x 10 inch four bladed propeller.

As a result we can state that a diameter reduction by 10% is necessary for the *2 > 3* blade change and a reduction by 16% for the *2 > 4* blade change.



A set of propellers having approximately the same power consumption.

All these relations are valid only for propellers of the same family having similar blade shapes. You can use the same diameter for different blade numbers if you change the width of the blades. Also the aerodynamic influence of additional blades reduces the power consumption by a small amount, which means, that the replacement 3 blade prop will consume slightly less power than calculated above. On the other hand it will operate at lower Reynolds numbers so that some additional losses can be expected. The formulas shown above should get you close to a working solution, though.