By: A M Wright **Date** 16/06/2006

Subject: Rudder design

1 INTRODUCTION

This document has been written in response to a request from Gordon Burton of GB Canoeing. It has been written to assist coaches and athletes in selection and care of rudders. It has been written with a non-technical user in mind, and does not cover any specific topic in great depth.

2 TERMINOLOGY

Leading edge – the front, highly curved part of the rudder that makes contact with undisturbed water first

Trailing edge – the back, sharp edge of the rudder

Root – the part of the rudder next to the boat

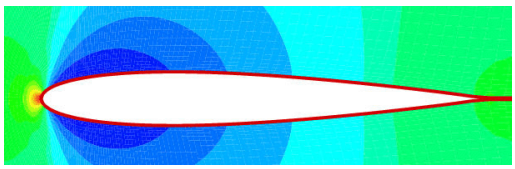
Tip – the opposite end from the root

Chord – the distance from the leading edge of the foil to its trailing edge

Span – The distance from the root to the tip

Planform area – the area of the rudder, when looking from the side of the boat, and as shown in the image above.

Cross section area – the area shown when looking vertically down on the rudder , as shown in the image below



Aspect Ratio – the ratio of span to chord. A low aspect ratio rudder is one where the chord is more than twice the span (i.e. aspect ratio below 0.5). A high aspect ratio rudder could equally be said to be one where the span is more than three times the chord (an aspect ratio above 3)

Angle of attack. – the angle which the rudder has been turned to in order to generate some side force

Sweep back – the angle away from the vertical of the leading edge

3 SOURCES OF DRAG

There are basically three elements of drag that can be produced by a rudder – skin friction, pressure and induced.

Skin friction drag – this is caused by the flow of water across the rudder, and is directly related to the wetted surface area. If a rudders planform area is twice the size, then the skin friction drag will be 4 times greater (the rudder having two sides !) everything else being equal. To complicate things, the skin friction coefficient lowers with increased chord. Therefore for a given planform area, the lowest skin friction drag is achieved with a low aspect ratio rudder (i.e. short span, long chord)

Pressure drag (also know as form drag) – this is due to the shape of the object. If the rudder is producing no lift, then so long as the thickness to chord ratio is 12% or below then the pressure drag is relatively low. If the rudder is at an angle of attack, then the pressure drag increases in a non-linear manner. Above 10-15 degrees of angle, the flow will begin to separate from the surface of the foil (i.e. the beginning of stall) and the pressure drag will be the largest source of drag on the rudder by an order of magnitude

Induced drag – this is the drag due to lift, caused by flow 'leaking' around the tip of the rudder (causing tip vortices as you see on aeroplane wing tips when landing). If the rudder is not producing lift, then the induced drag is zero. The higher the aspect ratio of the rudder (i.e. long span, short chord), the smaller the induced drag will be. The planform shape has an influence upon the induced drag, with elliptical (ie spitfire wing shape) being the most efficient. As the amount of side force is increased, the induced drag will increase as well.

The conflict between lowering skin friction drag and lowering induced drag is obvious; one requires a high aspect ratio, the other the complete opposite! There is no simple solution to this, and a compromise is required. If the athlete will be required to use a great deal of rudder (e.g. if there are large side winds) then a higher aspect ratio rudder should be used. If on the other hand the rudder is being used only to stop the boat yawing down the track, with no angle of attack on the rudder, then a low aspect ratio rudder should be used.

4 SHAPE

4.1 Planform Shape

An elliptical planform shape is best, with a relatively vertical leading edge. A rectangular shape is acceptable, but the indecued drag will be higher for such a rudder.

A swept back rudder will be less efficient (with respect to induced drag) than one where the leading edge is vertical, so should be avoided. The only time a swept back fin should be considered is if the water is very choppy, and or the athlete feels that the rudder is stalling ; the sweep to the leading edge will increase the range of angle of attack before stall occurs.

4.2 Cross section shape

The cross section shape is a secondary influence, so long as the basic aerofoil shape, as shown in the image on page 1 is followed. The thickness to chord ratio should be 12% or below. A standard NACA 00 section is suitable, the details of which can be found via an internet search.

5 PLANFORM AREA

As noted in Section 3 above, additional wetted surface area results in a drag penalty. Reducing planform area (with a two fold influence on the wetted surface area) will lower drag. However, if angles of attack greater than 10 degrees have to be used, then the pressure and induced drag will be dominating and the rudder area should be increased.

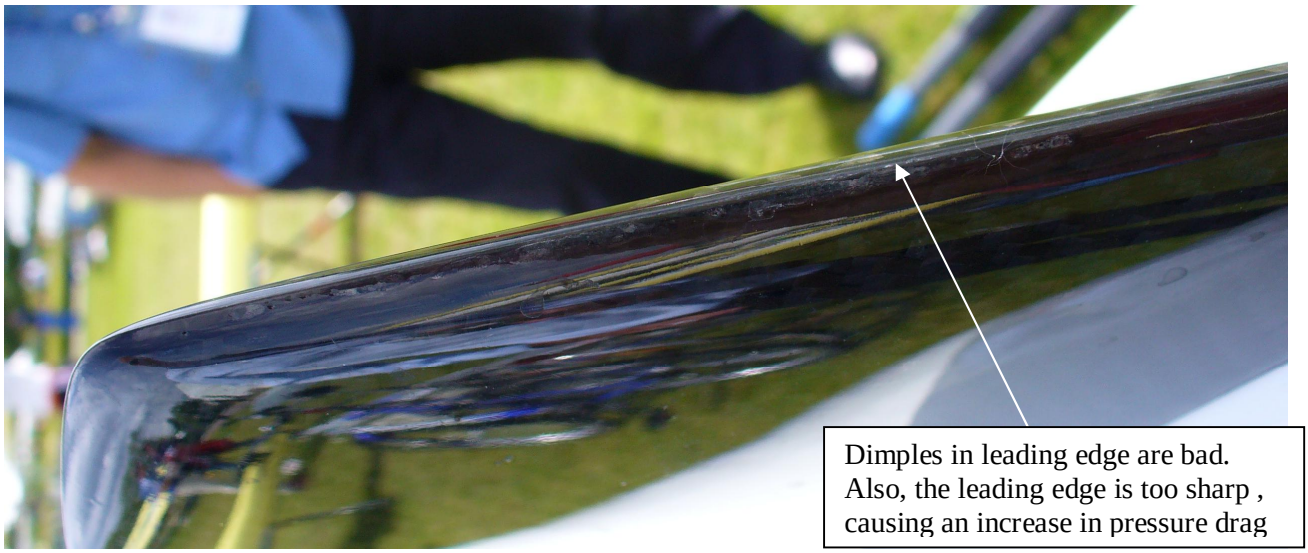
If the rudder area is to be reduced, then the desired amount of rudder should be cut away at the root. That is, keep the chord length the same, but shorten the span. If the rudder area is to be increased, then a higher aspect ratio could be achived.

6 FINISH AND MAINTENANCE

The surface finish of the leading edge and trailing edge of the rudder should be free of imperfections, especially the leading edge. If there are any defects (eg, scratches, dimples) in the leading edge the skin friction drag over the whole rudder will be increased considerably. The leading edge should be smoothly curved, with no sudden changes in direction. The trailing edge should be as fine as practically possible.

The rudders should have as smooth a finish as possible; at least 400 grit wet and dry sandpaper should be used, preferably higher, with sanding strokes in the chordwise direction. Particular care should be taken with the leading edge of the rudders. The whole surface of the rudder should then be polished in order to stop dirt sticking to the surface.

The images below of rudders (of canoes and rowing boats) have some comments attached to them, to illustrate the points made in this document-



Dimples in leading edge are bad. Also, the leading edge is too sharp , causing an increase in pressure drag

The leading edge here (aluminium plate) is very poor, and will cause a great deal of pressure drag, as well as significantly increasing the skin friction drag

The surface finish looks a bit rough, but it is difficult to tell from a picture. The rudder shape is correct, but the gap at the root near the leading edge could be reduced