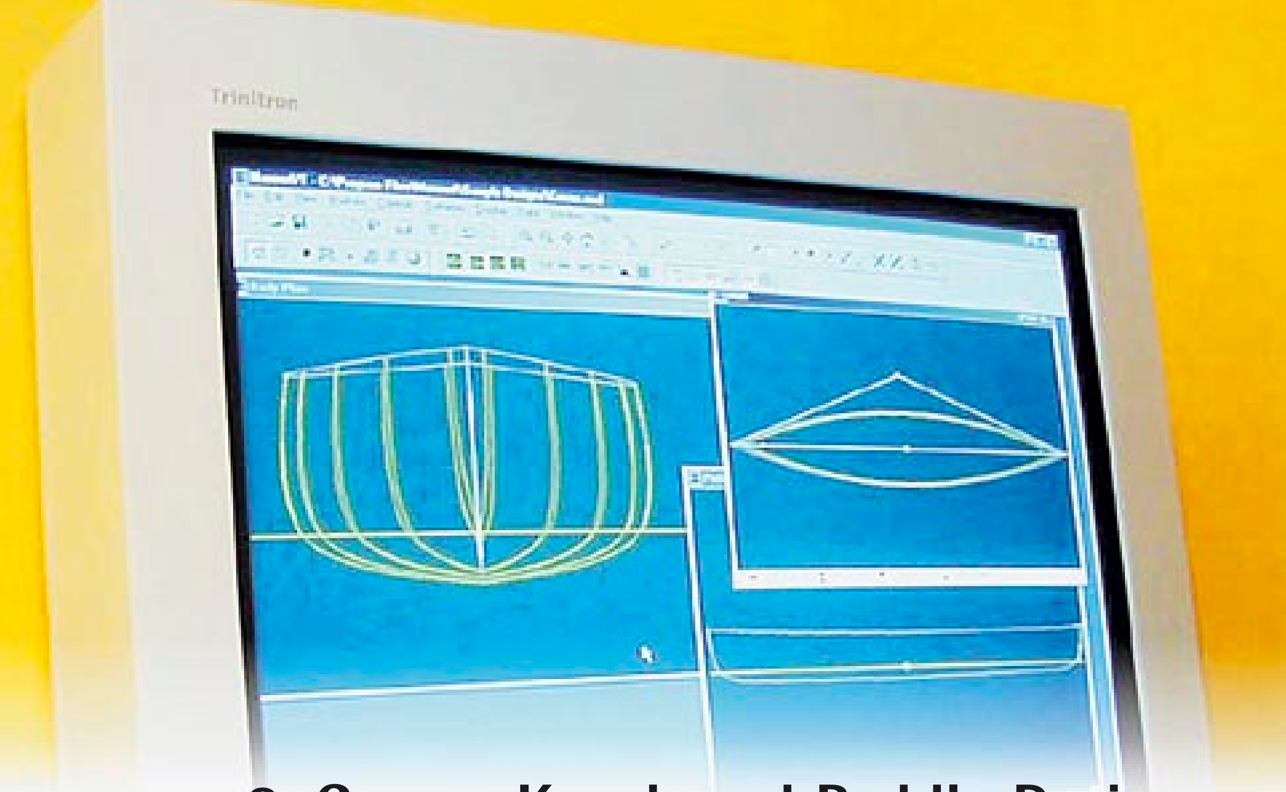


2 Canoe, Kayak and Paddle Design

To dream of improving a canoe, by making it faster, safer, more stable, more comfortable, prettier... To design in benefits and to see the benefits realised...
That's what design is about.

Introduction

The design of a canoe, kayak or paddle is part art and part science. The art aspect is usually fulfilled according to the old saying, "If it looks right, it probably is right".

Science aspects are an extremely complicated balance of many physical elements of performance, structure, and environment, and could mostly follow the phrase, "If it feels right, it's probably right for you!"

Some boats were designed to be paddled fast for long distances, some for surfing, some for spinning in circles and some to be always paddled in a swimming pool. The design criteria for each are very different, as are the needs of the paddlers.

A canoe, kayak or paddle that will suit one person probably won't be best suited to another. I hope the following chapter will make choosing or designing a canoe, kayak or paddle a little clearer, dispel myths, and help you look at equipment with a more discerning eye.

Terminology

In this chapter I will use the word 'boat' as a generic name for all paddled craft. Where I need to mention a more specific type, I will use the expression kayak, open canoe, etc. I will also avoid the technical language of naval architecture, unless absolutely necessary.

I touch upon shape, design, paddlers' needs, construction and material considerations; they are all interwoven elements in the design process.

The Boat

"There will never be a perfect canoe or kayak for all situations."

To get an understanding of the elements of a boat's design:

1. We'll look at a drawing of an open canoe and two different kayaks with some technical terms for certain parts of the craft, and its lines.

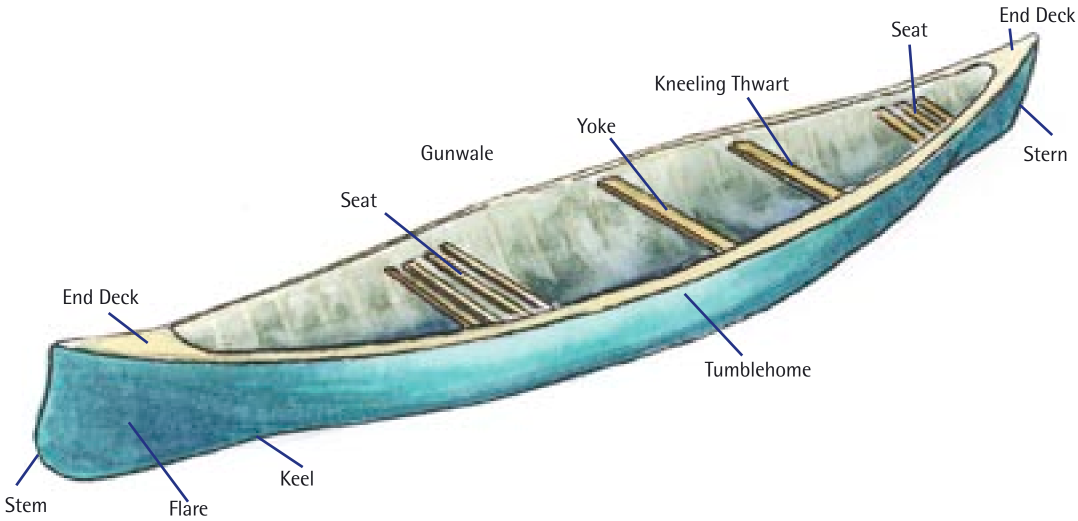


Fig 2.1 Drawing of an open canoe

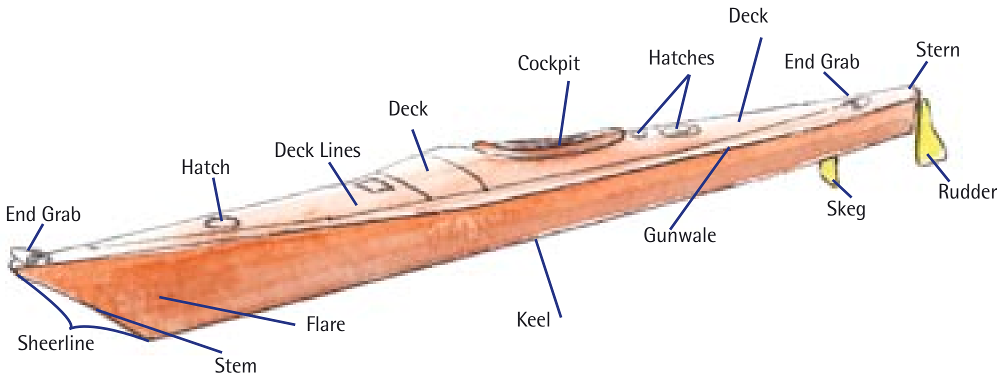
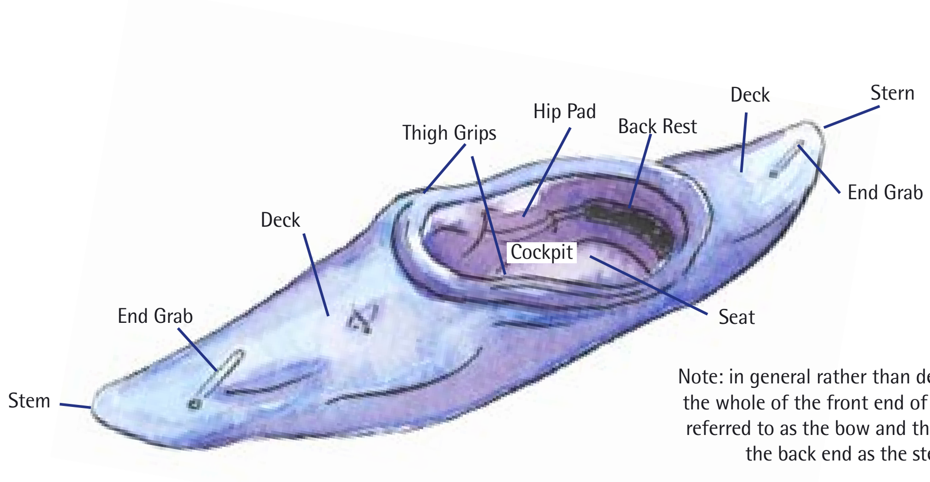


Fig 2.2 Drawing of a sea touring kayak



Note: in general rather than design terms, the whole of the front end of the boat is referred to as the bow and the whole of the back end as the stern.

Fig 2.3 Drawing of a white water kayak

2. We will have a look at where canoe design has come from, so that we can better appreciate what we have today.
3. We'll look at design features and problems.
4. We'll look at setting your objectives so that you can find a design with benefits that will suit you.

History of Canoe and Kayak Designs

Good designs are usually evolutionary, that is they have evolved over several attempts, one step at a time. This is necessary because skill and paddling technique move at a similar pace.

Classic Designs

Classic designs have evolved from aboriginal beginnings. The shape of touring canoes and sea kayaks has been developed over thousands of years, because "necessity had to be the mother of invention". Some boats such as the sea kayak and the open canoe are designs that can hardly be bettered by shape alone; the development has mostly been in technology, for durability and lower cost.

These same design considerations are still very relevant today, after allowing for:

- Modern man's larger build.
- Paddling Environment.
- Paddler's skill.
- Requirement for creature comforts.
- The fact that evolution of these designs is now slow.

Modern Designs

These designs are for recreational and competitive paddling. The shape of such specialist leisure craft has been developed to optimise performance in their specialism, such as playboats, canoe polo, slalom, sprint and marathon racing.

Evolution of these designs is very fast and (in the case of playboats) fashionable features are related to new moves.

Design Origins

The earliest canoes were designed by experience and 'eye'. Later, when boat builders were commissioned to build canoes and kayaks for clients, it became necessary to build 'half models' so that features could be discussed and a decision made. In the 19th century designs were finally developed on paper with a traditional set of line plans.

Today, some boats are designed on paper, some are hand shaped, and some can be designed on a computer, with the fundamental shape being carved on a CNC Routing Machine. Please note that computers do not design; their use is merely to replace the process of drawing.

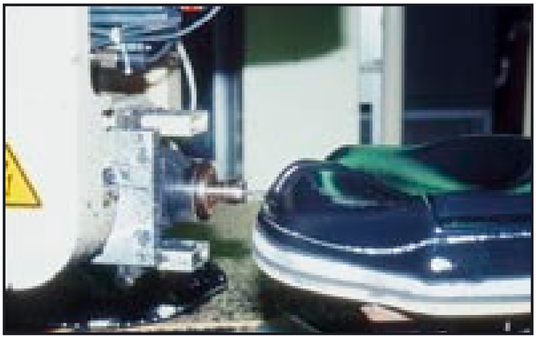


Photo 2.1 CNC Routing Machine

Today's designers are no different to aboriginal man; they use observation, experience, feedback from the users and more experience.

The Search for Lightness and Durability

All designs need to consider the limitation of available construction techniques.

Aboriginal

Dugouts, Birch-bark and Seal Skin

Developed over thousands of years these craft have taken advantage of locally available materials and environmental conditions. Although considered fragile by modern man, given the understanding of their limitations that the people who built them grew up with, they have been capable of incredible feats.

Recreational

Wood Era (after 1850)

The first wooden canoes and kayaks were built in Europe and in Canada. In Canada mass production was needed to supply the vast numbers that were required for exploration and wilderness travel. In Europe they were mostly custom-built for the wealthy Victorians to take advantage of their increasing leisure time.

Minimum building time was about 50 man-hours. This construction technique allowed a popular shape to be repeated, with canoes being built off moulds for the first time.

Folding (after 1908)

The first mass production of kayaks in Europe was in Germany. The development of the folding kayak enabled more people to buy a touring kayak, and to travel extensively (by train), and explore rivers. Thousands were built and exported worldwide.

Canvas and Wood (mostly after 1930)

This became more popular with the development of more affordable cars. It was no longer necessary to pack away your canoe, so costs came down again, as did the weight and ease of handling.

Stitch and Glue

During World War 2 waterproof glues were developed that allowed moulded, or stitch and glue ply canoes to be developed. Costs were about the same as wood and canvas, but they could be tougher and faster.

GRP and Advanced Composites

The use of Glass Reinforced Plastics (fibre-glass) started in the late 1950's, and by the mid 1960's all other methods were almost obsolete. This allowed the mass production of tough, light, and very long lived boats with almost no maintenance. Minimum building time is about 5 man-hours.

PE - Rotationally Moulded Polyethylene

This was developed in the mid 1970's and is today's most popular construction method, as the boats are extremely tough. A boat can be made in single or triple skin laminates, and a hull and deck can be produced in one piece, at very low cost. The materials are completely recyclable. Minimum building time is about 2 man-hours.

PE – Blow Moulded Polyethylene

This uses very expensive machinery and moulds for very fast moulding cycle times. Similar properties can be achieved as with rotationally moulded PE for single or twin skin mouldings.

Thermoform Plastics

These are single skin and vacuum formed, usually out of polyethylene or 'ABS'. This system has been used for the production of low cost open canoes, and a few kayaks.

Multi-Layer Sandwich

This method produces materials such as 'Royalex' and is mostly used for the production of light, rigid and tough open canoes.

These developments have continually brought down costs, so we now have paddlesport for all.

It's worth remembering that all these technologies remain useful today, each having unique benefits. It is also an interesting fact that the capabilities of advanced materials such as kevlar, carbon-fibre and epoxy resins were explored in the manufacture of canoes and kayaks long before they were used in such high-tech industries as aerospace and motor racing.

Design Performance Features and Problems

A canoe moves by forces acting on it. These consist of *active* forces such as from paddling or sailing, and *passive* and *external* forces such as from weight in the canoe or the effect of water or airflow on it.

Each force that acts upon a canoe causes some form of movement that can be a benefit, or a disadvantage. *All canoes are therefore a compromise*, being designed to optimise that compromise for the paddler's needs.

Hull Design

A hull will move in the following directions, either separately or (usually) jointly:

- Forwards.
- Backwards.
- Side to side.
- Up/downwards.
- Roll, which is its movement around its longitudinal axis.
- Pitch, which is movement around the transverse axis.
- Yaw, that is the rotation of the hull around its vertical axis.

"The ability to control these movements defines a design."

A boat turns as a result of the pressure on the hull being changed, such as by the paddler paddling harder on one side, or by the canoe being edged. A canoe or kayak doesn't turn as if on rails, its action is more like skidding, some boats more than others.

Speed

The forces opposed against you limit the speed you can paddle up to 'hull speed'.

Maximum hull speed (in knots) is up to 1.34 times the square root of the waterline, allowing for its shape, and the paddler's power. This is a rather arbitrary rule that was devised by Froude in the 19th century. Sprint canoes and sea kayaks that have a particularly high length to beam ratio can however exceed 'hull speed', as can play and surf boats whilst planing down steep waves. (N.B. 1 knot is 1.1515 miles per hour).

Photo 2.2 Sea kayak surfing

The limiting factors are:

- Skin friction on the canoe.
- Laminar Flow.
- Wave making drag on the canoe.
- Wind resistance on you and the canoe.
- Your strength and endurance.
- Weight of the canoe and its load (including you).

Skin Friction

At a cruising paddling speed, skin friction is the larger drag loss and is controlled by the total surface area of the boat. A playboat will out-sprint an Olympic sprint racing kayak for the first 2-3 strokes, because it has less wetted area and at low speeds skin friction has less effect than wave drag! At higher speed, the wave-making resistance/drag due to the playboat's short length limits speed up to 'hull speed', whilst the sprint kayak disappears into the distance.

Laminar Flow

It is extremely important to optimise the laminar flow of the water molecules on the craft's skin.

A very thin layer of water molecules will stick to the skin of a boat and move with it, effectively adding to the drag on the hull. Molecules attached to those move a little less quickly and others further away from the skin's surface less quickly still, until the water is at rest. If the boat is badly scratched, is irregular in shape, or has a rough finish, the boundary layer will increase in size, and become turbulent. It will travel with the boat and effectively add its weight to the drag of the boat, slowing it down.

> **Speed Potential**
>
> *An indication of the speed potential of a design can be sought by trying to reduce a design's Prismatic Co-efficient (Cp). This is found by dividing the displacement (cu metres), by a combination of the area of the widest point (sq metres), multiplied by the length (in metres).*
>
> **SL Ratio**
>
> *The ratio of S (Speed)/ Sq Root of the canoe/kayak's length or S/L Ratio is a useful way to compare the speeds of different designs.*
>
> *Therefore :*
>
> *A K1 has a Speed-Length Ratio of 2.*
>
> *A 3.5m touring kayak has a Speed-Length Ratio of .9.*
>
> *A 5m sea kayak has a Speed-Length Ratio of 1.5.*

Wave-making Drag

As speed increases, the waves that a canoe makes also increase, until at 'hull speed' the first wave is at the bow and the next transverse wave peaks in combination with the stern wave, adding additional resistance. Above this speed the canoe has to climb over its own bow wave, which with human power is unfortunately impossible. When a white water or slalom type of kayak is paddled hard on flat water with the bow lifted in the air, *it is not planing*. It is trying to get over its bow wave, with the stern being sucked down, due to the low-pressure area that is created with this type of hull shape.

A longer canoe or kayak will therefore go faster before this happens, so a long boat should always be faster than a short one.

The reduction of the bow wave is very important for high-speed canoes, so that modern racing canoes have a proportionally finer bow and fuller stern as a route to more speed.

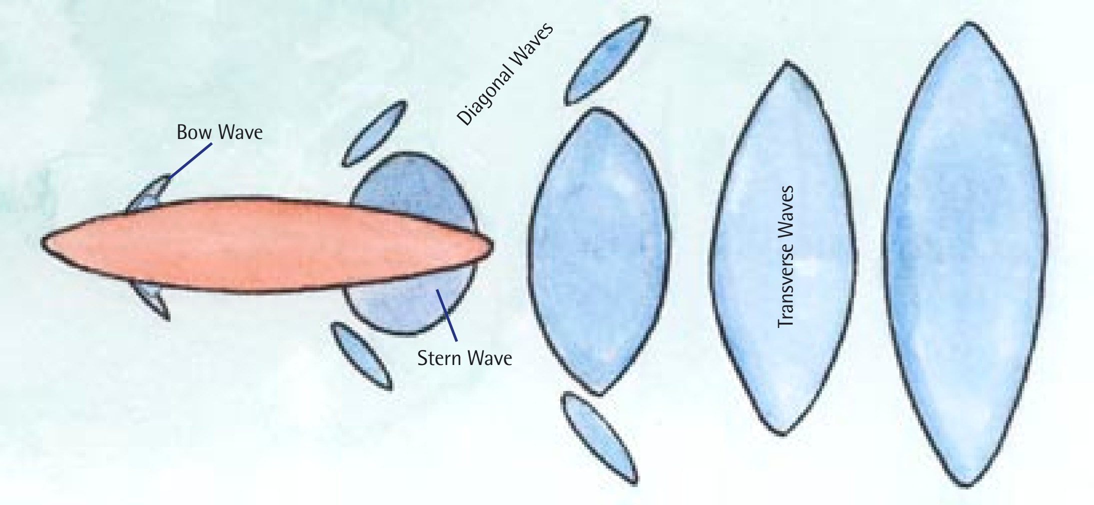


Fig 2.4 Transverse and diagonal waves

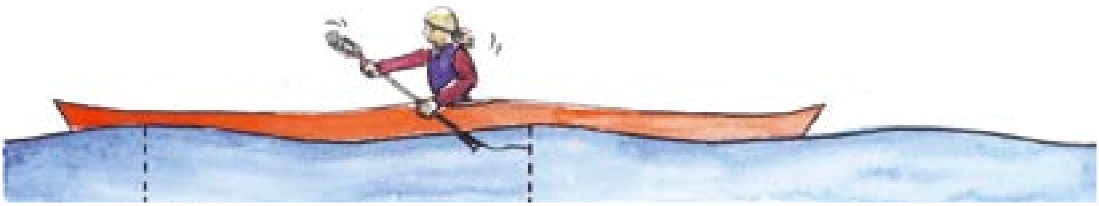


Fig 2.5a The ***theoretical*** *max hull speed of a kayak with a 15' waterline length is Speed (in knots) = square root of the waterline length x 1.34. Therefore maximum theoretical hull speed is 5.19 knots.*

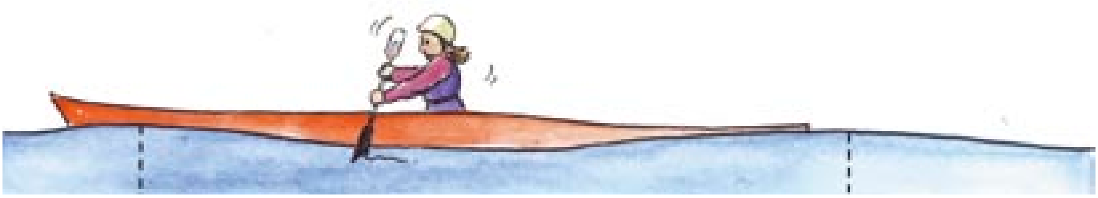


Fig 2.5b Sea kayak high speed cruising, wavelength almost the full waterline length of 14'. Speed is 5.02 knots. The kayak is starting to lift in the bow (2º off horizontal), and paddling effort is raised significantly.

Fig 2.5c Sea kayak in a speed burst that can only be sustained for a short time. The bow is now lifting 5º off horizontal and the wavelength has increased to 18'. Speed is therefore 5.68 knots. Over very short distances some designs can exceed 'hull speed' .

Fuller ends typical in higher displacement canoes will push up bigger waves, by the water having to accelerate faster to move around the canoe, and similarly at the stern of the canoe or kayak, the water has to accelerate where it is drawn back together. This will push up bigger waves, increasing drag and reducing speed potential.

Resistance to speed increases dramatically the higher the speed paddled. It is easily noted that low speed takes very little effort, but at higher speed it takes much more effort for a proportional increase in speed.

Length/Displacement Ratio

In a boat, its fineness and displacement is usually referred to as the Length/Displacement Ratio. This ratio is obtained by dividing the waterline length cubed, by the total displacement of the boat, which includes you and your load.

This ratio can range from .65 for long light boats to 2 for short heavy ones. A recreational touring kayak can average 1.5.

If you look at the height of waves and imagine the weight of water in them, then that weight represents the energy you are putting into paddling.

Length is however waterline length, not length overall. Some 5.2m (17') sea kayaks are effectively only a little over 4.5m (15'). In a surf or playboat you can take advantage of gravity to accelerate so that effectively you get the bow wave crest aft of the stern. The trough of your bow wave moves towards the crest of the stern wave and they start to cancel out, so that wave-making resistance is reduced while frictional resistance continues to increase. You are effectively surfing not only the wave you are riding, but also your own bow wave, which due to the flatter hull form has dynamically lifted you to the water's surface.

Photo 2.3 Gravitational pull, combined with lift accelerates kayak

This is so dramatic that modern designs can plane whilst side-surfing, and so can now spin through 360 degrees so easily that it can be achieved using only body rotation.

Wind Resistance

Wind resistance can be substantial, and can be simply tested by choosing a windy day to paddle. Paddle with the wind, and then against it; you can feel a huge difference. The bigger the boat, and the higher you sit, the greater the effect.

Stability

Stability is your resistance in a boat against capsizing, and depends on the centre of gravity (CG), and the centre of buoyancy (CB). If the CG's vertical alignment falls far enough outside the CB you will

Fig 2.6a-c Figures a and b show a stable situation. C shows a paddler leaning into a wave to keep his CG over his CB, and using a bracing support to ensure he doesn't capsize.

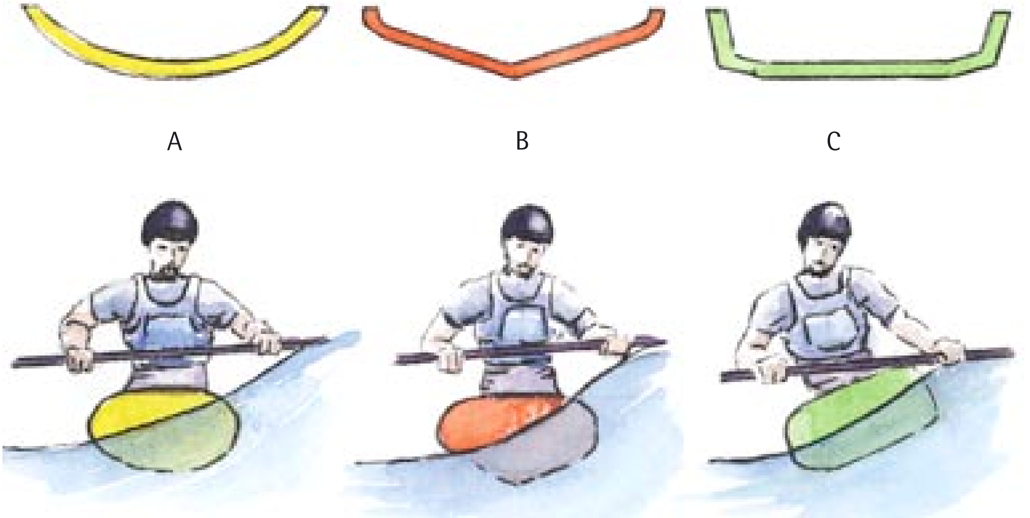


Fig 2.7 *A: Round section kayak which has moderate progressive stability on flat water and in waves.*

B: An extreme 'V' section kayak with poor initial stability on flat water and in waves.

C: A flat section kayak that has high stability on flat water, but is unstable in waves, as the hull tends to want to follow the contour of the waves. Freestyle boats exploit this to achieve remarkable moves.

NB: A semicircular shape is used for sprint racing canoes as it has the minimum wetted surface area, and is therefore fastest, but it also has least form stability of all shapes.

capsize unless you support (provide additional force upwards) on a paddle stroke. Different types of canoe have varying tolerances to allow movement of your body and the canoe (CG), without causing a capsize risk. If you look at Fig 2.6c you will see a paddler about to capsize.

A canoe or kayak needs to be a platform from which you can comfortably apply your paddle strokes in the direction of your choice.

It should neither be unstable, so that you can't concentrate on what you are wanting to achieve, nor over-stable, as that will mean:

- It is wider and therefore slower both in speed and changing direction.
- If you capsize it will be harder to perform an Eskimo Roll, if it is possible, with your boat.
- It is also heavier.

CB and CG

CB - Centre of Buoyancy is the centre of the displaced volume of water.

CG - Centre of Gravity is the centre of the mass of the canoe and paddler.

In an upright craft on flat water the CG is usually on the centre line of the boat immediately above the CB.

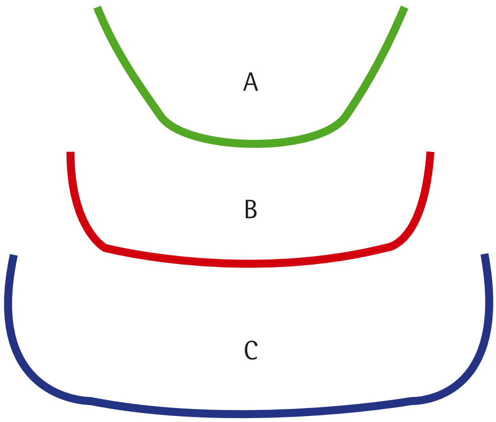


Fig 2.8 Profiles of a sprint kayak(A), a white water kayak(B) and an open canoe(C), all are stable enough, but not too stable

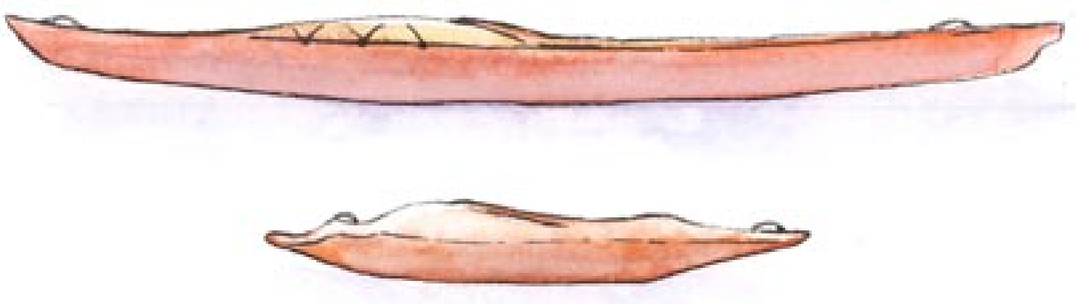


Fig 2.9 A side profile drawing of a sea kayak (top) and a playboat (bottom), to the same scale

- A flat-hulled boat will be stable on flat water, but unstable on waves.

(A boat with a low seat will be more stable than a boat with a higher seat).

Turning or Manoeuvrability

A boat's centre of effort and its centre of gravity will affect its turning. A canoe or kayak generally rotates about its CG, with the power of forces acting upon its form or shape that will determine the rate of turn. A long boat with a straight keel will have more resistance to turning than a highly rockered playboat.

For beginners, the first challenge will be to paddle the boat in a straight line. The ease with which a boat can be made to do this can be improved by:

- A moderate design with a longer and straighter keel.
- Stern-down trim or better still, a skeg.

A balanced design, with the hull shape being nearly symmetrical, front and back will be easier to control and more predictable than a design that is asymmetrical in hull shape.

Advantageous features for directional stability (anything that reduces manoeuvrability):

- Long straight keel.
- Well rounded hull cross-sections.

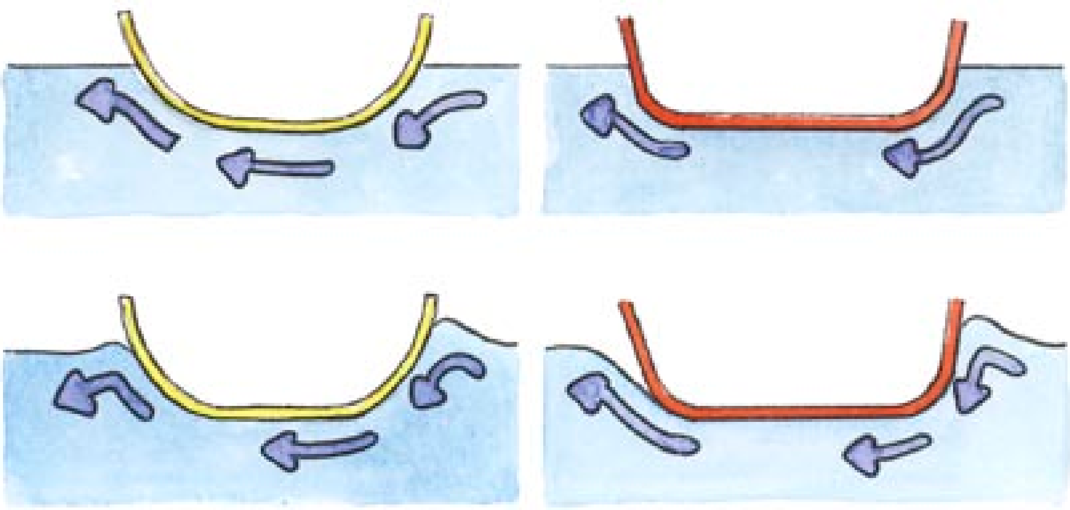


Fig 2.10 Cross-sectional drag at low speed (top), and high speed (bottom) for both round and square sections

- Skeg or rudder systems.

Advantageous features for manoeuvrability:

- Short keel line.
- High rocker.
- Flat hull cross-sections with break-away edge.
- Foil shaped gunwales and low deck line.

However all good designs are never taken to an extreme, as even a racing kayak, or sea kayak has to turn sooner or later, so it must have a small amount of rocker. A boat without any rocker would feel dead.

A boat with too much rocker for the paddler's ability or experience would be uncontrollable.

It's all a compromise.

Paddling skills can be used to modify the design's natural characteristics. The paddler can lean to the side, forwards or backwards to change the hull shape presented to the water, to lower the boat's resistance to turning. A good design will be developed to take advantage of this.

If you trim a boat down at the stern (perhaps by the moving of the seat back or by the loading of heavier equipment), you will decrease the turn rate and increase the canoe's directional stability. This may be an advantage or disadvantage to you. If you trim the bow down, perhaps by leaning forward whilst paddling with a broad sweep stroke and also tilting the canoe away from the turn, you can reduce the keel's resistance and increase the rate of turn.

In Summary

Directional stability and manoeuvrability are direct opposites, which can be modified slightly by edging/leaning and stroke, but you can't have the best of both. *A longer boat with a straighter keel will therefore turn more slowly than a shorter boat with a rockered hull shape.*

Different cross-sections can give a boat a very different feel and performance potential. Three extreme examples are:

Sprint Racing Kayaks

These have a semi-circular cross-section for minimum skin friction and resistance. This is very unstable, but very fast.

Open Canoes

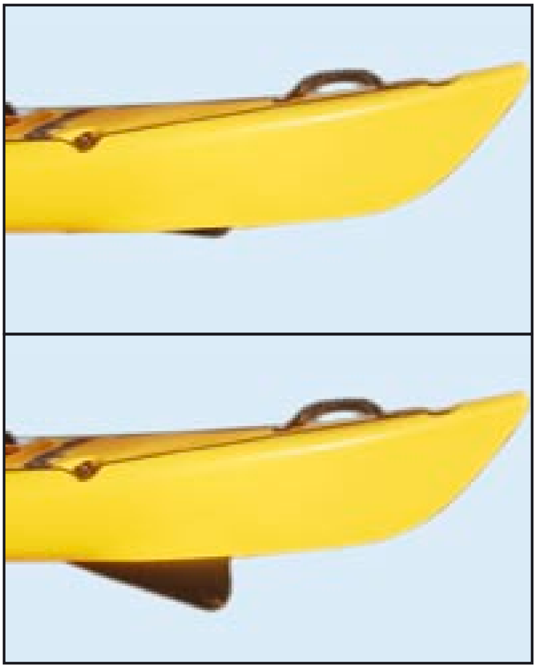
These have broader and flatter cross-sections, which will show tendencies to be V'd, or a shallow arc. Whilst subtle, the difference in feel can be large.

White Water Playboats

These have an almost flat hull with very hard edges, for planing and spinning, and the deck is low profile so that it can move three dimensionally with the minimum force. Experts can use a harder sided but less forgiving shape, which has the bonus of carving better turns. Intermediate paddlers can choose slightly softer edges, which are less likely to catch, and are much easier to roll.

Skegs and Rudders

Wind and waves will exert a turning force on a boat (yaw); the more highly rockered the design, the more it will be turned by these forces. A sea kayak can be balanced on one heading whilst unbalanced on another. To counteract this problem with paddle strokes is extremely tiring, so it is usually necessary to have a method of trimming such kayaks.



Skegs

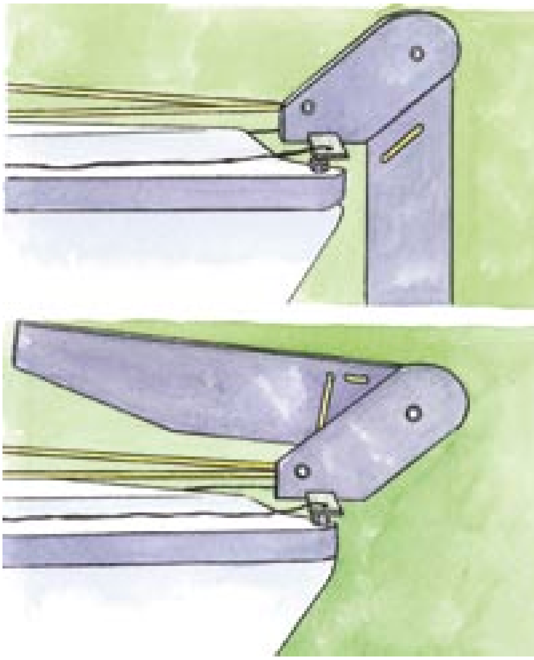
Some boats are fitted with fixed or lifting skegs. This is the nearest you can get to "having your cake and eating it."

Recreational paddlers use them to make their craft more directional, especially at the beginner's stage. Modern man needs to achieve quickly, and these give the easiest route to directional stability without learning to trim, lean or edge and apply advanced strokes.

Photos 2.4a-b Kayak with skeg up and down

Sea kayakers have found that lowering and trimming a skeg will substantially improve the directional stability and control of a kayak in stronger wind and waves. This happens when wind and wave action apply a force on the boat's centre of lateral resistance. The skeg shifts the centre of lateral resistance backwards and balances the boat's tendency to turn into wind.

The skeg needs to be positioned as far back as possible, but not so far that it comes out of the water



when paddling over waves. The larger the open skeg box and the larger the cross-section of the skeg, the greater the drag will be.

Rudders

These are commonly used in sea kayaks, and always in sprint and marathon racing kayaks.

A rudder is however a more complex solution to a skeg, but more flexible. A rudder can be used to both trim the boat and change its direction. A rudder is more vulnerable to being damaged, as it is always exposed.

Fig 2.11 Rudder system

By changing its angle of attack to the water, the rudder generates a combination of lift and drag that turns the boat.

The paddler's feet operate a rudder. The steering mechanism is connected to the rudder's yoke by wire or rope. Sliding foot pedals are the simplest method of steering, but make good paddling technique difficult, whilst a 'T'-Bar and full width footrest is more efficient but less easy to adjust. Most rudder blades can lift if they hit an obstruction and, in the case of sea kayaks, can be lifted up and parked on the deck.

There are great differences in quality in rudder systems. The better systems with airfoil-sectioned blades are highly engineered to be wobble free and immediately responsive. They are therefore relatively expensive due to their sophistication.

Less expensive rudder systems usually have flat aluminium blades and simple head systems and controls, which are fairly resilient against the knocks that a rudder will inevitably get.

Deck Design

A deck's shape is designed in combination with a hull shape, and should usually:

- Shed waves as quickly as possible.
- Catch the wind as little as possible.
- Provide the paddler with adequate foot space.
- Allow a kayak to complete an Eskimo roll easily by being well-rounded. (A flat deck would cause the paddler much more effort, as the kayak would want to rest upside down with the paddler acting as a keel.)
- Allow the paddler the closest possible paddle entry to the centre line of the boat to improve paddling efficiency.
- Take end grabs, hatches, deck lines or other performance and safety equipment as needed.
- Be shaped by the cockpit to deflect waves over the cockpit coaming edge, to help keep water from getting under a spraycover.

As with hull shape, all ideals have to be compromised. Perhaps one of the most complicated design types is the sea kayak, where all the above considerations are essential. The sea kayak overcomes this by having a high bow, due to the raised forward sheer line, which will :

- Break a wave and therefore help shed the wave quickly.
- Ride over a wave using dynamic (buoyancy

and its flared shape) lift.

Aft of the bow, the deck drops away as much as possible, to reduce windage, with hatches and deck lines kept as low in profile as possible. The cockpit then peaks, with the deck rising a little more before it to drive waves over the cockpit edge to keep you dry inside, though at the cost of driving it into your chest if your lucky, in your eyes if not!

Photo 2.5 End Grabs and 'Shockbloc' footrest

White water expedition kayaks are usually shaped purely for shedding water, and keeping the cockpit dry.

Photo 2.6 'MicroBat' front deck

The latest playboats use volume around the centre of the kayak to support the paddler whilst 'cartwheeling', and to ensure that the kayak is retentive (stays in the stopper). Low volume and foil-shaped ends help the kayak slice predictably through the aerated water. The extreme contouring in the front and back provides dynamic lift in a 'loop' and other moves, that volume alone can't achieve, to get the paddler airborne.

Photo 2.7 Power Pocket

Comfort and the Application of Effort

"The benefits of a great design will never be realisable if you aren't comfortable and in control."

Control and *power* are essential to the safe management of canoes and kayaks. However, a boat should also be comfortable enough that paddlers can maintain their concentration for as long a period as possible. We're all built differently, so a boat that is comfortable for you might not be for somebody else. This can usually be improved by personally outfitting a canoe or kayak (see Chapter 4). *Feedback* from the boat, and *power transmission* through the boat are essential.

Control Comes From Contact With Your Boat

In sprint and marathon racing and in a recreational kayak, you will have two contact points, the back of your seat and footrest. This enables the kayak to be powered forward, held stable, and turned slowly but effectively in a two dimensional plane.

In a white water, surf or polo kayak you will have three points of contact, your seat, thigh grips and footrest so that you can control the kayak in a three dimensional plane more responsively.

Fittings must:

- Hold you in when you want to be held, but not impede your exit when you want to get out. This is *essential*.
- Not be so padded that they isolate you from the feel of the canoe, or prevent you from transmitting your energy into performance.
- Make you so comfortable that you can concentrate for as long as you might have to sit in your boat. For sprint paddlers that might be

five minutes, for play paddlers that might be an hour, but for an expedition sea paddler that

might be days.

Seats

Seats should combine grip, with support. Kayaks mostly use bucket seats, with adjustable backrests. A playboat may only be sat in for an hour at a time so the top paddlers go out of their way to fix themselves in rigidly.

A sea kayaker will, however, need to be able to stretch out and will need a much greater support area. An open canoe will need comfortable seats, and the ability to sit on the back edge of a front seat so that it can be paddled solo.

Photo 2.8 'XR' seat and back strap system

Photo 2.9 Polyethylene and wood/webbing canoe seat

Thigh Grips

These are essential for white water competition and recreational kayaks, and are increasingly found on sea kayaks. They should be adjustable for length, and have enough hook to grip your thighs (wherever on your thighs you find it most comfortable), but not so hooked that you can't flatten your legs to bail out *quickly* if necessary.

Footrests

Footrests are essential in most kayaks, and desirable in even the lowest cost recreational kayak. They can be found in several forms, which should all give you the maximum contact area at an angle that is comfortable.

Recreational Footrests

These are simple, low cost units, which are usually an easily adjustable pedal footrest on a runner, on which you place each foot.

A better footrest is found in racing kayaks, which is a broad plate footrest that extends across the full width of the kayak. This enables you to place your foot in the most comfortable place. They are not as easily adjusted.

For use in advanced white water the footrest must be shock absorbing. A full plate footrest should be able to stop the paddler going over or under (if trimmed properly) in even the most aggressive impact situation. Properly trimmed, they could prevent broken ankles or legs or, in the worst case scenario, save lives.

The Shockbloc

This form of footrest transmits the paddler's effort direct into the end of the kayak, to transmit power into speed, and to stop the distortion of the shell that foam alone would cause. They have been developed because the ends of playboats have got so small that there isn't room for any other system.

Fitted Buoyancy

Buoyancy bags effectively fill the ends of the canoe with air, keeping water out and making the canoe easier to recover.

Buoyancy bags or bulkheads and hatches are essential for beginners and all paddlers in extreme or open water. They save lives.

End Grabs

These must be:

- Comfortable enough to hold the boat when carrying it, or hold onto the craft if swimming.
- Strong enough to be used in a rescue, which in white water may need to be in excess of 500kgs.
- Not easily degraded due to wear, or UV exposure.
- Replaceable.

- Not spin around whilst swimming and be capable of trapping your hand or fingers.

Volume and Buoyancy

A boat needs enough volume or shape buoyancy to:

- Carry a paddler, plus equipment.
- Generate lift to allow the canoe to handle adequately in all anticipated conditions.

Many white water paddlers are consumed by volume statistics. I confess I find them of little use. I've seen a 90kg person trying to squeeze into a kayak designed for a 65kg person. The only way is to test them for yourself.

A number of leading manufacturers have now designed and built various sizes (up to five) for a model of kayak, so that paddlers of different sizes can get the same enjoyment and performance from their kayak.

What counts is your experience and assessment of whether that design feels right and has the features you want. A sea kayak or open canoe will be designed with a displacement assessment, but that is no substitute for your experience, or lack of it, and the storm or testing rapid you may paddle into.

Volume doesn't equate to safety. A safe canoe or kayak doesn't exist. A safe and prepared paddler does.

Dream your dreams and make a decision that is right for your paddling and your aspirations. Don't be a sheep!

Cockpit Shape

Cockpits range in size from the smallest, which are usually found in sea kayaks or white water racers, (at 70cm long x 37cm wide) to recreational touring boats (at110cm long x 50cm wide).

Design considerations are:

- Recreational kayaks should have a large open cockpit for ease of entry and particularly exit.
- Maintaining the rigid structure of the boat.
- Linking the shell to the seat, thigh grips and back strap where appropriate.

Cockpits which might expect to have waves wash over them, need to be covered by a spraycover, and therefore need an effective cockpit rim. They should not be too small for ease of entry and emergency exit, or so large that the spraycover would implode under water pressure. The modern shape is called a 'keyhole' cockpit and is usually about 72.5cm long x 42cm wide. The modern keyhole cockpit has evolved due to the increased severity of water paddled and the improved technical ability of the modern neoprene spraycover. Entry and exit can be made easier by lifting the front of the cockpit, relative to its rear. The paddler should be able to sit on the seat and lift at least one knee out at once.

Setting Your Objectives

A good design must be a marriage of practical and aesthetic values for any aspect of paddlesport.

You must ask yourself many questions before you begin choosing a new or better boat:

Practical

- What do I want to be able to do with this boat, and who else might use it?
- Where will it be used?
- How fast must it be?
- How stable?
- How manoeuvrable?
- How much storage space?
- What safety and other fittings does the boat need?

Aesthetic

- How the canoe should look? "Beauty is in the eye of the beholder."
- What colours to use for safety and to match other equipment?

Words can give you clues, but all canoes and kayaks have different benefits. Try as many as you can with an open mind, and they will educate you, reward you with more fun, and give you the opportunity for more adventures.

A good boat will be the one that fits you and in which you can achieve your objectives. It might never be the best at anything, but it will be comfortable, forgiving, responsive and fun. It will talk to you through its movement, and you will understand instinctively those movements, and it will be an extension of your body. It will be a trusted friend.

The Paddle

A paddle is a more personal choice than a boat, because your use of it has to be *instinctive*. You will change your canoe or kayak more easily than you will change your paddle.

A paddle must:

- Be shaped to allow the paddler control whilst executing many different paddle strokes.
- Be shaped and constructed to transmit the paddler's power smoothly to the water, whilst being as light as possible.
- Communicate what is happening in the water's flow and currents back to the paddler.

A paddle has two important parts, the blade and the shaft, which for an open canoe includes a handle, and it is important that both work in harmony. A light paddle shaft with heavy blades can feel unusable.

Kayak Blade Shape

Flat Blades

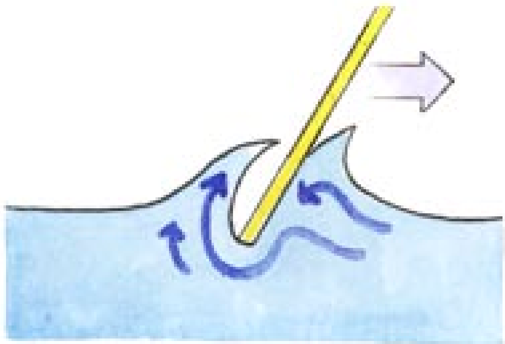


Fig 2.12a A flat paddle blade allows greater cavitation behind the blade

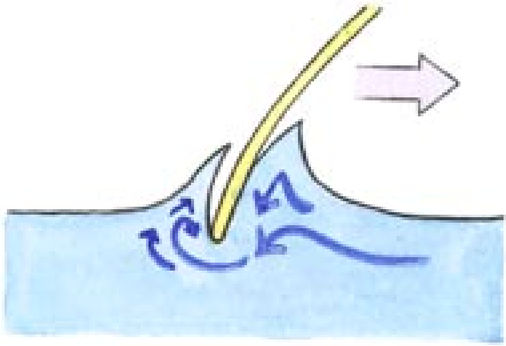


Fig 2.12b A curved blade is more effective in reducing cavitation and increases propulsion

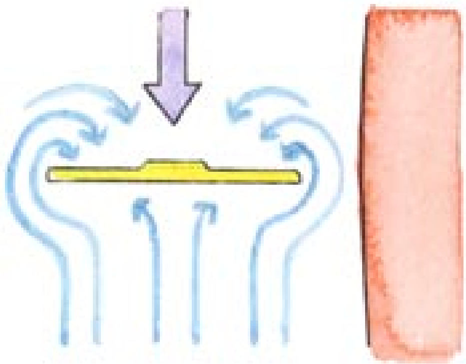


Fig 2.13a Flat or curved blade and water flow during paddling

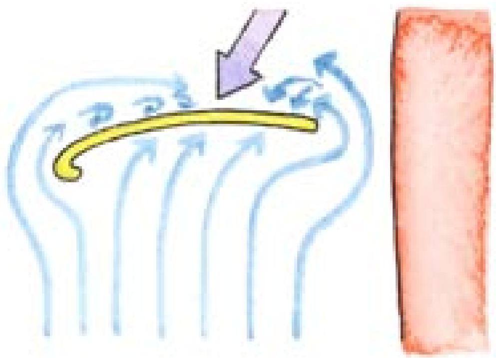


Fig 2.13b Wing blade with water flow during paddling

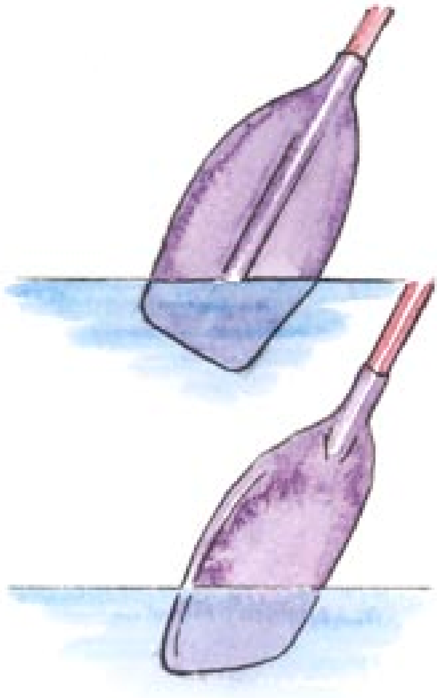
These are the most common for complete beginners because they are cheap and the same paddle can be used by right or left handed people.

Curved Blades

These are the most usual blade shape. They are curved along their longitudinal axis, whilst flat (or slightly convex or concave) across the blade face. These are efficient in forward paddling strokes as they 'catch' the stroke better than flat blades. Curved blades are most popular for touring and for white water. They enable the paddler to be able to scull for support, roll and perform other complicated paddle strokes in endless combination. The paddle must therefore be able to move from a power to many other strokes smoothly. This will necessitate a smooth back to the blade so that both faces can be used.

Wing Paddles

These are designed mostly to power kayaks forwards and are the latest, fastest and most extreme shape for a speed paddle. They are unusual in that they are designed not to be pulled straight back, but back and out from the side of the canoe. This action generates pull and lift, hence its name 'wing'.



The back of a blade is rarely used except to lean on the water's surface for resting; it can therefore be ribbed for strength. It also reduces rear blade turbulance and ensures that more paddling energy is used effectively. (See *Fig 2.13b).*

End Profile

The end profile of blades can be Symmetric or Asymmetric. The latter is now far more popular for all paddling due to its improved balance in the 'catch' part of the paddling phase.

Blade Size

Kayak blades are usually similar sized for recreational use, but for advanced paddlers they will come in different sizes; a smaller paddler would use a smaller blade shape, whilst a bigger and stronger paddler should use a larger blade.

Fig 2.14 End profiles of symmetric (top) and asymmetric (bottom) blades

Feather

Feather refers to the angle at which the blades are offset to each other on a kayak paddle. Traditional Inuit paddles have no feather, and flat paddles are usually offset at 90º, so that both left and right handed paddlers can use them. A 90º feather was introduced for racing; as the top blade slices through the air the bottom one pulls the boat through the water. However, a high degree of feather increases the risk of wrist injury.

Feather is a matter of personal comfort and type of paddling. Most touring and racing paddles have about 70º of feather, and some playboaters have as little as 45º.

Open Canoe Blades

Open canoe paddles are flat, to make all paddle strokes smooth, with a cross-section shape that is smooth for sculling the canoe sideways, 'J' strokes, and other strokes that use both faces of the blade.

With a kayak blade the exit phase of the stroke is least important, but for the canoe this is where the paddler must execute the steering phase, so a curved blade would be less reliable.

Blade shapes vary to allow for paddlers' needs, water conditions and depths.

Material Construction

Injection Moulded 'ABS' or Nylon

These blades are sometimes with glass or carbon-fibre reinforcement for increased rigidity and strength. They have moderate to good performance at low to moderate cost. They are usually very strong and durable, and make great all-round paddles.

Wood

Wooden blades have great feel and are shock absorbing. They are however more fragile to use and require maintenance. They are especially good for touring.

Carbon

Carbon blades transmit energy very well, are very light, very expensive and are hard and unforgiving. These are used by most racing paddlers.

Kevlar

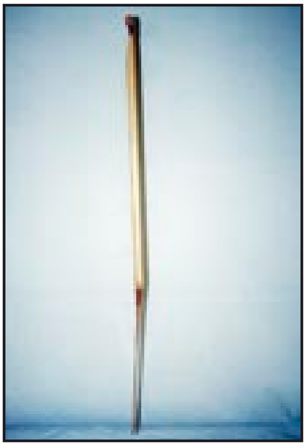
Kevlar can be included with carbon in a blade to improve impact resistance, though edges can't be trimmed neatly so they usually have a furry appearance, best used in white water paddles.

Paddle Shafts

Photo 2.10 A selection of paddles, square tipped (a), beaver tail (b) and otter tail (c)

Paddle shafts are as important to consider as the blades. It is the shaft that will transmit your energy, and the water's feel.

Shape & Grip



Paddle shafts can be round or oval in cross section. The oval shaft gives increased strength in the direction of pull, and the paddler a better feel of the paddle.

Some top quality round shafts have a section of plastic bonded to them for a hand grip, to increase the feel of the shaft whilst still allowing for the technology's ability to only make a rounded shaft.

Most shafts are longitudinally straight. Some kayak paddles have cranked handgrips to allow the paddler's hands a better and more comfortable grip.

Some open canoe shafts are bent to give a more efficient 'catch' phase for open canoe racing. They are difficult to steer with, so the paddler has to switch paddling side to compensate.

Photo 2.11 Bent shaft canoe paddle

An open canoe paddle has a grip for the top hand to allow the paddle to be pulled or twisted in manoeuvres.

The grip can be variations of the following shapes:

- 'T' Grip – usually used by racing or white-water paddlers to give the optimum grip.
- Palm Grip – usually used for touring as it is more comfortable and relaxing to use and where the ultimate grip is not required.

Construction

Paddle shafts can be manufactured from:

Wood

The shaft is made from a solid piece or by laminating different woods, that optimise strength, resilience and low weight; ash for compression and tensile strength, and spruce for light weight cores are the most common performance woods.

Alloy

The shaft is anodised to prevent corrosion and covered with PVC handgrips because of its cold feel. These can be extruded or welded tubes.

Glass or Carbon Reinforced Resin

These are usually laminated over a mandrel, giving the lightest weight, highest strength, and highest cost.

Length

Length varies considerably with your height, your boat's width and the performance you want.

A short paddle can accelerate your boat quickly. If it is too short, you won't be able to reach the water.

A long paddle will be slow to accelerate, but will make long distance paddling more comfortable. If it is too long, it will be extremely difficult to use.

As an example of the variations, paddles for kayaks will vary from:

Sprint & marathon	210-225 cms
Slalom	195-208 cms
Surf	190-200 cms
Freestyle	190-200 cms
Canoe polo	198-208 cms
Sea touring	210-330 cms
Inland touring	208-220 cms

Paddles for canoes:

Inland touring	50-63 cms
White water	48-54 cms

You Will Never Feel a Great Paddle!

A paddle which is not great will leave you with nagging doubts that it might suddenly slice the water and tip you in. It might be heavy; its shafts might be

Further Reading

Canoe Design and Construction, Byde A, 1975, Pelham Books, London, 0-7207-0862-1

A good book in the basic principles though out of date now for specialist canoes and kayaks. The construction element of the book covers period GRP technology.

The Shape of the Canoe, John Winters, 1996, self published

Based on a series of articles written in the US Canoesport Journal between 1988 and 1991, a technical look at Canoe Design.

The Bark Canoes and Skin Boats of N.America, Adney, Edwin T and Chappelle H, 1964, Smithsonian Institute, Washington DC, Stock No 047-001-00021-8/Catalogue No S13.3:230

Graham Mackereth

Graham started canoeing when he was 15 years old with a £12 Granta Kingfisher double. He and his scouting friends started building and racing their own boats, and he designed and built his first boat in the summer holidays of 1967. Before long he was competing at international level in marathon, sprint and wild water racing.

In 1971 he started up Pyranha, and although in 1972 he was a part of the Munich Olympic Team he decided to retire from serious competitive paddling. However, his competitive instinct remained so he took up sailing an International Canoe, an activity where he has had some success and a great deal of enjoyment.

His passion for design has found success and outlet in a number of ways. World Championship winning slalom designs from 1977 to 1985 (mainly in co-operation with Albert Kerr and Richard Fox), expedition designs that started with Mike Jones' 1976 Everest Expedition, and currently pushing the limits with freestyle and advanced white water designs.