FatSparrowRacing

Advanced Sail Trim

Well trimmed boats are easier to sail upwind. They require minimal rudder input, go a little faster and point a little higher than the competition around them. They sail like this because not only are they are in balance and trimmed for optimal VMG, but the skipper has also taken wind and water conditions into account.

DF65 and DF95 baseline settings are intended to get the new DF owner up and sailing as quickly as possible. The baselines have been derived over time as an average setup for average conditions. They do not really address the infinite variety of wind and water states we might need to tune for.

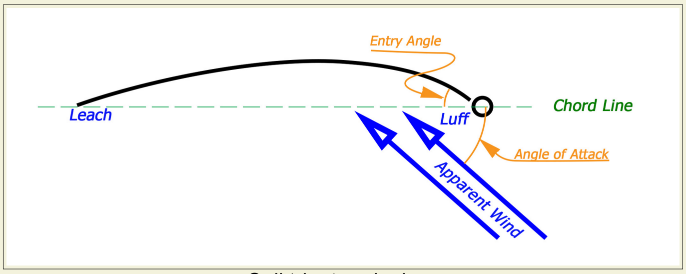
To gain a better understanding of how to adjust your basic tune for different conditions, there are three aspects of sail trim that need to be looked at:

- Camber or depth and shape in the sail.
- Twist – the change in the angle of the sail from the boom to the top of the mast.
- Sheeting angle – how close to the centre-line the sail is sheeted.

Terminology

Before we start, we need to introduce some important terminology:

- Apparent Wind – is the wind that would be measured by a wind indicator on the boat. It is a combination of the true wind and the wind caused by the boat's movement through the water (the boat wind).
- Angle of Attack – is the angle the apparent wind makes with the chord line of the sail.
- Entry Angle – is the angle that the luff of the sail makes with the chord line.
- Stall – a sail stalls when the angle of attack increases to the point where the sail can no longer generate lift.

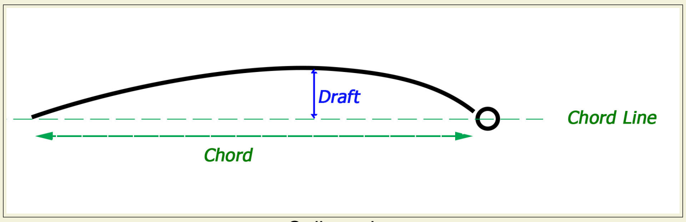


Sail trim terminology

These concepts are all inter-related. When the boat is steered close to the apparent wind, the angle of attack is small. If we steer too high and the angle of attack approaches the entry angle, the luff of the sail will start to flutter and lift decreases. If we steer too low and the angle of attack becomes large, the sail will stall and stop generating lift. So there is a range of angles of attack that work. Boat setups that result in a wide range of usable angles of attack are said to give a wide steering groove. Such setups are easier to sail, less likely to stall when coming out of a tack and accelerate more readily in gusts.

Camber

Camber measures the fullness, or depth of the sail. The term refers to the distance from the chord line of the sail to the point of maximum depth. You will sometimes see this represented as a percentage.



Sail camber

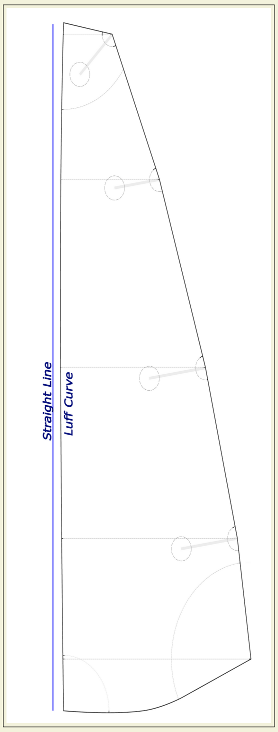
Camber gives the sail power. More camber (fuller sail) equates to more power; less camber (flatter sail) equates to less power. Camber is controlled by outhaul and mast bend

Outhaul

Sliding the silicone rings that hold the clew hook along the boom will adjust the camber of the sail. Outhaul has most effect along the foot and lower third of the sail, but less at the top where the sail narrows towards the peak.

Mast Bend

Sailmakers build a small amount of luff curve into the mainsail. When the sail is run up a straight mast, this extra material is pushed back into the sail creating depth up the luff and adding to the camber.



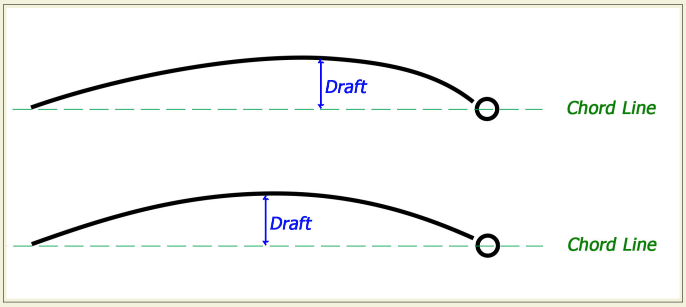
The amount of luff curve varies from one sail to another, but you will find the mainsail on the DF95 A rig (the largest of our DF sails) will have about 5mm of curve built in. This doesn't seem like much, but it can have a profound effect on both the amount of camber and the position of the maximum depth point along the chord line.

Note the very small difference between the straight line and the luff curve in the diagram. If we introduce mast bend, that extra material is pulled forward and the sail flattens. On our masthead rigs, bend is mostly controlled by the fore and aft position of the mast gate in combination with forestay and backstay adjustment. We get a little bit of bend induced by backstay tension applying a lever action through the mast crane, but not that much. On these rigs, the mast bend is relatively even up the mast.

On fractional rigs (DF65 A, B and C), we have backstay tension applied at the top of the mast, while forestay tension is applied lower down. The asymmetric tension allows greater control of bend in the top section of the mast and we can use backstay to flatten the top of the sail as the breeze increases.

Position of Maximum Depth

The position of maximum depth along the chord line will determine some characteristics of how the sail performs in different wind and water conditions. If the position of maximum depth is well forward, the sail will have a distinct knuckle in the camber and a fuller entry angle at the luff. When the position of maximum depth is set towards the chord midpoint, the camber is more symmetrical and the sail has a finer entry angle.



Position of maximum depth forward and aft

We can control the position of maximum depth on the mainsail by careful application of mast bend. As mast bend increases, more sail material is pulled forward and the camber becomes more symmetrical. The straighter the mast, the more camber up the luff. Remember, there's only about 5mm of curve added up the luff, so you don't have very much to play with. You'll know you have gone too far when diagonal creases start to appear in the sail.

Unlike the mainsail, the jib on all DF rigs is cut with a straight luff. Any sag caused by a loose forestay will push material back into the sail in the same way that straightening the mast does to the mainsail. When the forestay starts to sag, camber increases and the position of maximum depth moves forward.

Luff tension

Both DF classes have controls to tension the luffs of the jib and mainsail – cunningham and/or halyard. On most sails (radio yachts and full size) these controls have the effect of adjusting the position of maximum depth of the sail. More luff tension will move the position of maximum depth forward.

A by-product of DF65 and DF95 class rules that limit some aspects of sail construction, mean that these controls have nearly zero effect on sail shape on DF boats. Use the cunningham on mainsails to remove any sag between luff ties up the mast and cunningham or halyard to remove wrinkles up the luff of the jib. Set them firm, but not tight.

Camber and Entry Angle

A side effect of increasing camber, or moving the position of maximum depth forward, is that the entry angle will get larger. This in turn means the minimum angle of attack increases and we have to steer a little lower for the same sheeting angle.

We generally want a fine entry angle on the jib so that the boat will point closer to the wind. Keeping forestay sag to a minimum will help here. We can accept a fuller entry angle on the mainsail because it will be sheeted closer to the centreline of the boat.

Camber Downwind

Camber has a marked impact on downwind performance – particularly when running. Too little camber will result in the boat being noticeably slower on this point of sail. Outhaul is the effective control for downwind camber with mast bend having little impact.

Setting Camber

When setting camber, consider the following:

- More camber gives more power, but comes with a fuller angle of entry and increased drag.
- Less camber gives a finer angle of entry and enables the boat to point high, but produces less power and may be slow downwind.
- An aft position of maximum depth (symmetrical camber) produces a high lift/drag ratio but stalls more quickly when the angle of attack increases. This type of shape is said to give a narrow steering groove and is best suited to flat water.
- A forward position of maximum depth results in a lower lift/drag ratio (less lift, more drag), and wider entry angle so you can't point as high. However, the shape is more forgiving and gives a wider steering groove – good for sailing in waves, or a gusting, shifty wind.

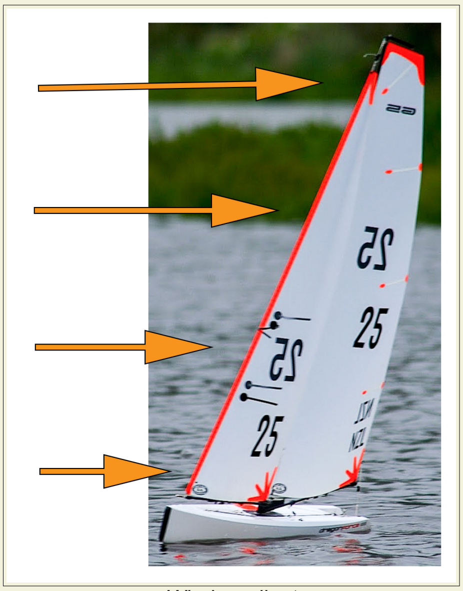
Twist

Twist describes the change in relative angle of the sail from the boom to the peak. You can see the effect of twist in the following image by noting the changing angles of the battens up the leach of each sail.

Twist – Note the changing angles of battens up both sails

Effect of Wind Gradient

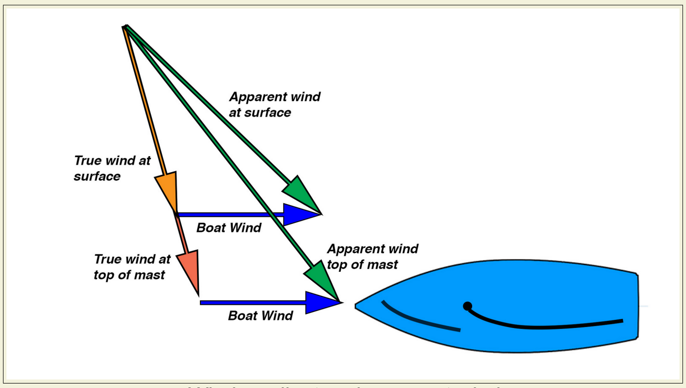
Due to surface friction, the true wind is not as strong at the surface as it is at the top of the mast. This is known as wind gradient.



Wind gradient

Wind gradient is most pronounced in light breezes. As the breeze strengthens, surface friction has less effect and the difference between wind strengths at the top and bottom of the mast is reduced.

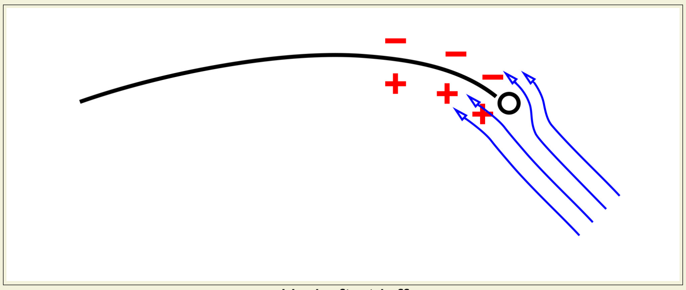
We know that the apparent wind on the sails is a combination of true wind and the wind caused by the boat's movement through the water (the boat wind). However, due to wind gradient, the stronger true wind up the mast creates both a stronger apparent wind and a wider apparent wind angle at the top of the sail.



Wind gradient and apparent wind

Effect of Updraft

As the wind approaches the leading edge of the sail it is deflected towards the leeward side of the sail by the areas of higher pressure on the windward side and lower pressure on the leeward side.



Updraft at luff

This effect is known as updraft; the term being borrowed from the world of aeronautics where aerofoils typically operate in the horisontal plane.

The world of aeronautics also tells us that for tapered or swept wings, the updraft effect increases out towards the tip of the wing. Both the mainsail and jib are tapered and the jib, in addition, has a significant amount of sweep. So we can expect increased updraft on our sails as we move towards the top.

The effects of updraft can be detected well ahead of the sail. On our sloop rigged boats, the jib is largely working in updraft generated by the mainsail (in addition to creating updraft of it's own) which allows the jib to be sheeted at a wider angle than the mainsail.

Controlling Twist

The combined effect of wind gradient and updraft means that the top of the sail is working in a wider apparent wind angle than lower down. To maintain optimum angle of attack, the upper part of the sail must be twisted out relative to the lower part of the sail to match the more open apparent wind angle and prevent the upper part of the sail from stalling.

Mainsail twist is controlled by the vang. Jib twist is controlled by the topping lift. Vang and topping lift controls raise or lower the end of the boom, easing or tensioning the leech of the sail. As tension on the leech is eased twist increases; applying more leech tension reduces twist.

It is normal to set jib and mainsail twist about the same and many skippers will look at the leeches of both sails from aft and check that the curve of the jib leech matches the curve of the mainsail. Take care not to set the jib leech so tight that the slot between mainsail and jib is closed off, as this will choke flow of air across the leeward side of the mainsail, reducing the power it generates.

If using telltales, you can check for correct jib twist when the upper and lower jib telltales flutter in unison. If not using telltales, check for correct twist by slowly heading into the wind. The jib should begin to luff simultaneously and evenly from head to foot. There is too much twist if the top of the jib luffs first. Too little if the lower section of the jib luffs first.

Backstay and Twist

The effect of backstay on mainsail twist is most pronounced on our DF65 fractional rigs. As backstay is tightened, the top of the mast comes aft and the mainsail leach relaxes. A less pronounced effect is seen on the masthead rigs where the lever action of backstay tension at the aft end of the mast crane forces some bend in the mast.

Backstay is not the preferred twist control as it effects so many other aspects of trim. Changing backstay tension will also change:

- Mainsail twist
- Mainsail camber and position of maximum draft
- Forestay sag
- Topping lift tension and therefore jib twist in the reverse direction to mainsail twist.

You need more backstay tension if the forestay is sagging in the gusts. Remember that if you change backstay, everything except sheeting angle will also need to be adjusted.

Setting Twist

Think about the following when setting twist:

- In light breezes, we need twist because:
  - Wind gradient is most noticeable when the breeze is light.
  - Sails are more prone to stalling in light air. Twist prevents the stall by easing flow in the top section of the sail.
- Reduce twist in a moderate breeze. You can set less twist in moderate breeze without stalling flow. Less twist adds power and improves pointing.
- As the boat gets overpowered in heavy breezes, flatten sails and add twist to spill power.
- Set more twist in light and heavy breezes and less in a moderate breeze.
- Less twist will help pointing, but more twist tends to be faster.
- More twist gives a wider steering groove and you are less likely to stall coming out of a tack.
- Set more twist in waves to accommodate the rapidly changing angle of attack as the boat bounces around.
- Reduce twist in smooth water to get power and point high.

Sheeting Angles

Sheeting angles of mainsail and jib are a little obscure in that we tend not to think about the angle so much as the distance the end of the boom sits out from the centreline when close hauled. The advantage in thinking about sheeting angles is that the concept of an angle is consistent from rig to rig, but the boom to centreline measurements can change with rig size.

Mainsail Sheeting Angle

We want to trim the mainsail as close to the centreline as possible without causing the lower part of the sail to stall. Further up the sail, twist will reduce the chance of stalling, but at the bottom, twist is zero. The amount of mainsail camber and the position of maximum draft also determines sheeting angle. A deeper camber with a larger entry angle must be sheeted closer to the centreline than than a flatter sail.

In practical terms mainsail sheeting angles in the range of 3º to 4º seem to work for DF boats. Go to the smaller end of the range when the foot of the sail is powered up with maximum camber. Ease sheeting to a larger angle if flattening the sail in heavier breezes.

Jib Sheeting Angle

Full sized boats, typically use headsail sheeting angles in the order of 7º to 8º, but our DF boats need a somewhat wider headsail sheeting angle than this. While smaller boats do tend to have wider headsail sheeting angles, the more significant factor is the positioning along the boom, of the jib pivot point.

Moving the jib pivot point some 20% to 25% along the jib boom is a feature seen on many radio yacht designs. In conjunction with the counterweight at the forward end of the boom, it promotes the jib's tendency to gybe over when running before the wind – gull winging. However, when beating, the offset pivot point also has the effect of moving the jib boom sideways to a more windward position, compared to a jib boom pivoted at the tack of the sail.

Moving the jib boom to windward effectively closes the slot and we must compensate with a wider sheeting angle to maintain flow over the back of the mainsail.

Setting Main and Jib Sheeting Angles

Trimming sails to a desired close hauled sheeting angle is impractical. Far better to measure the distance from centreline to the end of the boom. The following tables show the distances from the centreline to set the end of the boom for a range of sheeting angles.

For main boom sheeting, an easy method is to use a straight-edge from mast to backstay. Measure from the centre of the main boom to the face of the stick.

Measure jib sheeting from the centre of the mast to the end of the jib boom.

Sheeting Angle (Degrees)	A+ Rig		A Rig		B Rig		C Rig	
	Main	Jib	Main	Jib	Main	Jib	Main	Jib
0	0		0		0		0	
1	5		5		5		5	
2	10		9		9		9	
3	15		14		14		14	
4	20		19		19		18	
5	25	16	24	16	24	16	23	16
6	30	19	28	19	28	19	27	19
7	35	22	33	22	33	22	32	22
8		25		25		25		25
9		28		28		28		28
10		31		31		31		31
11		34		34		34		34
12		37		37		37		37
13		40		40		40		40
14		43		43		43		43
15		46		46		46		46

DF65 sheeting angles

Sheeting Angle (Degrees)	A Rig		B Rig		C Rig		D Rig	
	Main	Jib	Main	Jib	Main	Jib	Main	Jib
0								
1								
2	12		11		9		8	
3	18		17		14		12	
4	24		23		18		16	
5	30		28		23		20	
6	36	26	34	26	27	25	24	28
7		30		30		28		30
8		33		33		31		33
9		37		37		34		36
10		41		41		37		39
11		45		45		40		42
12		48		48		44		45

DF95 sheeting angles

Looking back at the baseline settings for each boat, we can now see that mainsails were being set up at around 3º to 4º and jibs at around 11º to 12º.

Think about the following when setting sheeting angles:

- Increasing camber gives more power, but you need to sheet in closer to the centreline to keep the boat pointing high.
- The boat will point higher for the same sheeting angle if you flatten the sails, but this generates less power.
- Since the jib sheets out wider than the mainsail, it may be set with less camber than the mainsail to enable it to a point high.
- Sheet sails more closely in steady breezes and flat water. Sheet wider in waves or strong, gusty winds.
- Resist any temptation to sheet the jib so close that air flow is restricted across the back of the mainsail.

A last Word on Mast Rake

If struggling to find a combination of settings that give good performance in the conditions of the day, think about whether altering mast rake might assist. Altering mast rake has the effect of moving the sail plan forward or aft and changes the balance point of the boat. Aft gives more weather helm (tendency to point higher); forward more lee helm (tendency to point lower).

If you have to de-power the mainsail (reduced camber, more twist, wider sheeting angle) more than you want for the conditions, consider raking the mast further forward. Conversely, if the boat doesn't point well, or doesn't seem to be responsive to wind shifts (particularly lifts), consider raking aft.

Remember that changing the mast rake requires a corresponding change in position of the mast gate to maintain the same mast bend.