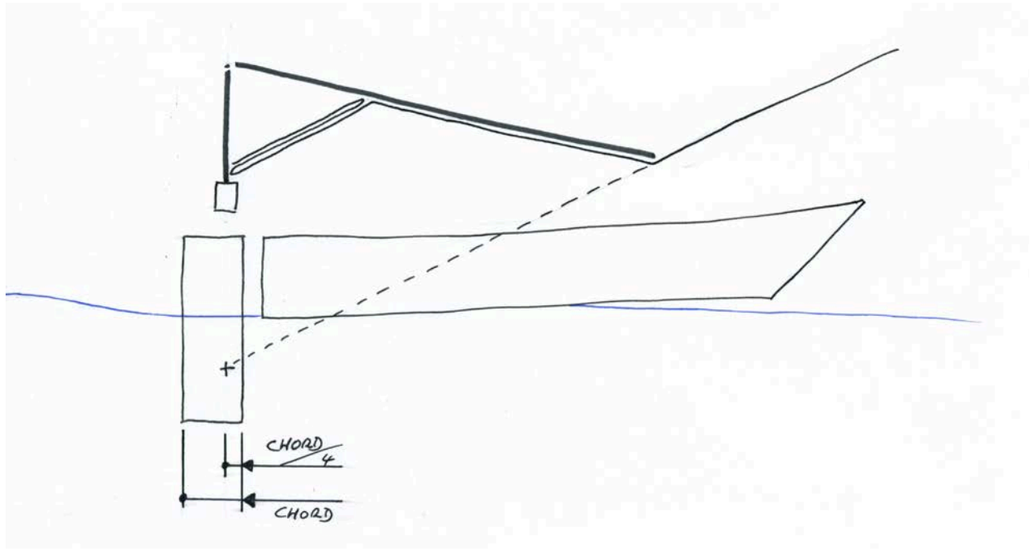

Figure 4.1.1

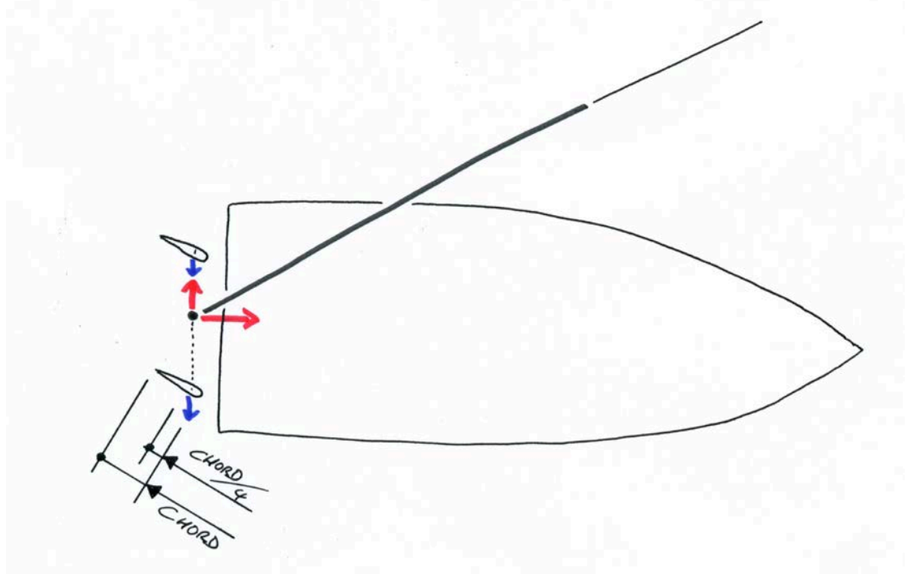

Figure 4.1.2

4. Use of combined 'keel-rudders' to avoid leeway

4.1 Principles

If the *WINDFLY Rig* is mounted at the stern of the boat this allows the keel and rudder to be combined into one, or two, 'keel-rudder(s)' which is / are used to steer the boat and also resist the sideways component of the kite load.

The centre of lift of a symmetrical foil is located 25% of the chord length behind the leading edge. The *WINDFLY Rig* is mounted above the quarter point of the 'keel-rudder' so that the 'keel-rudder' rotates until the sideways force of the kite is balanced by the lift provided by the 'keel-rudder': the 'keel-rudder' adjusts automatically to offset the sideways component of the kite load.

A traditional keel or centreboard requires some leeway to occur to generate the lateral load to balance the sideways force of the wind. Using the combined 'keel-rudder' system eliminates leeway. This may allow a deeper hull form, such as a deep V hull form, to be adopted without increasing resistance due to vortex shedding as water flows across the hull. The deeper hull form improves course keeping in heavy seas, and also reduces pounding in waves.

A tiller may be used to steer the boat. If more than one 'keel-rudder' is used, the tiller pintle is placed on at the midpoint of the line that connects the 'keel-rudder' pintles, this ensures that the distance between the stern of the tiller and the 'keel-rudders' remains constant as the tiller and the 'keel-rudders' rotate. Therefore a fixed length linkage can be used to connect the end of the tiller to each of the 'keel-rudders' so that all turn together.

As the 'keel-rudders' rotate the drive force introduces an additional moment which acts to increase the rotation of the 'keel-rudders'. The additional rotation is small and can be easily balanced using the tiller. Taking moments about the pintle:

$$M = (F_Y - L)\left(\frac{C\cos\alpha}{4}\right) + F_X\left(\frac{C\sin\alpha}{4}\right) \qquad \text{[equation 4.1]}$$

If L = F_Y, the restoring moment to be provided using the tiller is:

$$M_T = -F_X\left(\frac{C\sin\alpha}{4}\right) \qquad \text{[equation 4.2]}$$

And the steering force to be provided on the tiller:

$$F_T = -F_X\left(\frac{C\sin\alpha}{4}\right)\left(\frac{p}{q}\right) \qquad \text{[equation 4.3]}$$

Where:

C is the chord length of the 'keel-rudder'
p is the distance from the tiller pintle to the quarter point on the chord of the 'keel-rudder"
q is the distance from the tiller pintle to the point at which the tiller is held.

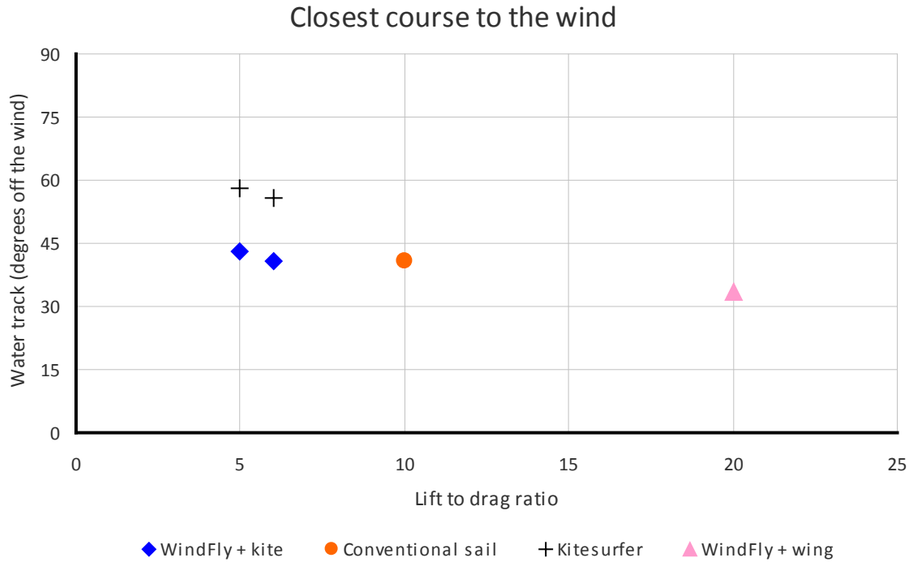

Figure 4.3.1

4.2 Operation at very low speed (without steerage way)

Of course the 'keel-rudder' only works to balance the sideways component of the kite / wing load if the boat is moving fast enough for the 'keel-rudder' to generate sufficient lift. Unless the boat has steerage way the stern will tend to swing round to follow the kite.

To prevent the stern swinging after the kite, the kite lines can be run through a guide at the bow so that the bow follows the kite until steerage way has been built up and the lines can be released from the guide. Typically the bow guide will be used during launch and retrieval of the kite / wing when the kite / wing is likely to be flown at low elevation for sustained periods.

4.3 Achieving a course closer to the wind

Kites generally form less efficient aerofoils than conventional sail rigs. Therefore kite boats do not typically point as close to the wind as conventional sail boats. The maths indicates that if the *WINDFLY Rig* is mounted so that leeway is avoided the boat will be able to achieve a course as close to the wind as can be achieved by a traditional sail boat.

		Kite surfer		WindFly Rig without leeway				Conventional
				Kite		Wing		Sail
Lift / Drag ratio		5	6	5	6	20		10
Kite lines inclination	(degrees)	30	30	30	30	30	Heel (degrees)s	20
Effective Lift / Drag ratio		4.3	5.2	4.3	5.2	17.3		9.4
Angle of kite / sail / wing relative to the wind	(degrees)	13.0	10.9	13.0	10.9	3.3		5.7
Angle of force (combined lift + drag) relative to the wind	(degrees)	103	101	103	101	93		96
Angle of force (combined lift + drag) off the bow	(degrees)	60	60	60	60	60		60
Leeway	(degrees)	15	15	0	0	0		5
Water track angle off the wind	(degrees)	58	56	43	41	33		41

Figure 4.3.2