The WindFly Rig

Driven by the wind. No heel. No leeway.

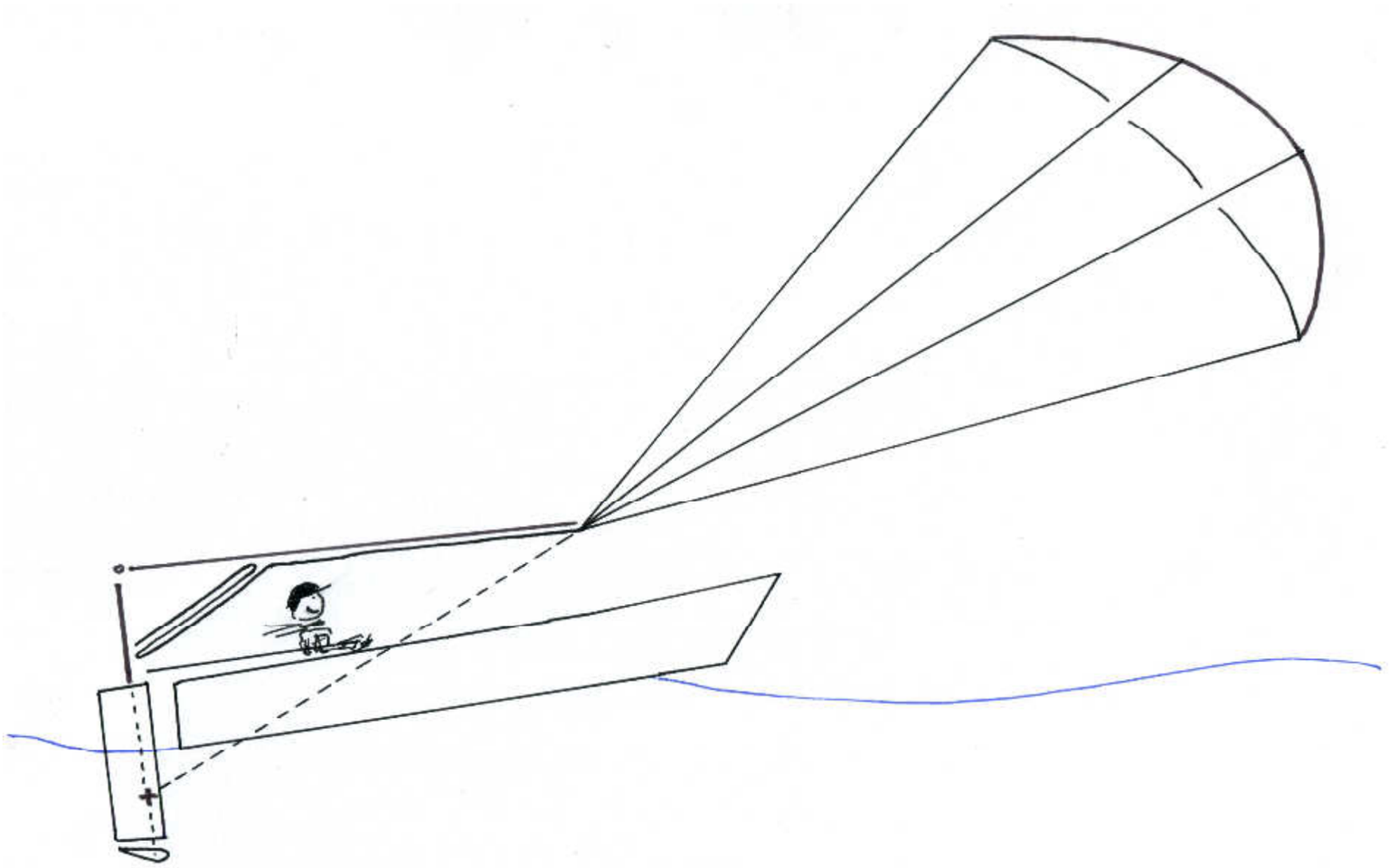
The WindFly Rig can be used to drive yachts, dinghies and kayaks, planing boats, foiling boats, sledges, buggies and karts.

This report records progress in the ongoing development of the WindFly Rig.

UK patent GB2508660. International patents pending.

The WINDFLY Rig

Driven by the wind. No heel. No Leeway.



The *WINDFLY Rig* connects a kite or wing to a boat to drive the boat forward without making the boat heel over.

The *WINDFLY Rig* automatically adjusts to control heel as the kite or wing moves, no external control or energy input is required.

Without heel there is
- No need for ballast;
- No need to hike out;
- No need for wide hulls or multihulls.

The *WINDFLY Rig* can be mounted so that leeway is avoided.

The *WINDFLY Rig* can be fitted to a yacht, dinghy, kayak, buggy or sledge. The *WINDFLY Rig* can be fitted to the transom of a motor boat in place of the outboard engine.

The *WINDFLY Rig* allows the kite or wing to be manually controlled from the cockpit. The *WINDFLY Rig* can be rigged so that the kite or wing is flown automatically without active control by the crew.

The *WINDFLY Rig*:
- Can drive a vessel forwards or backwards;
- Limits the maximum load that is applied to the vessel by the kite;
- Automatically takes in slack to maintain tension in the kite lines;
- Can be mounted on commercially available 'off the shelf' hulls;
- Allows the foils to be raised for access to shallow water;
- Includes a quick release system to separate the kite from the vessel.

Boats using the *WINDFLY Rig* are
- Faster;
- More stable;
- More fun.

With the *WINDFLY Rig*
- Boats plane upwind as well as downwind;
- Foiling boats are stable.

The *WINDFLY Rig* is simple, practical, fast and fun.

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UK patent GB2508660
International patents pending

The WindFly Rig principles were developed by Bruce Martin. Bruce is a keen kitesurfer and sailor. The WindFly Rig brings these interests together to use a kite to drive a boat without heel or leeway (the rig also works for sledges and buggies). Physical prototypes of the WindFly Rig have been developed and tested by Assorted Projects Ltd.

The WindFly Rig has been developed through a series of prototypes to the current version which is designed to be mounted in place of an outboard motor on standard 'off the shelf' planing motor boats. This version of the WindFly Rig is currently undergoing sea trials. Perhaps there has been too much focus on applying the WindFly Rig to a planing hull at the expense of achieving earlier success with displacement hulls.

Collaborators are welcomed, whether working directly with Bruce or on parallel projects. If you plan to develop the WindFly Rig commercially: it is patented, get in touch and we can agree a way forward.

Please get in touch if you would like more information or to collaborate.

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1. Advantages of the WindFly Rig

This section provides a summary of the advantages of the WindFly Rig relative to a conventional sail rig. A more rigorous analysis is provided in the documents available to download from www.WindFlyRig.com.

No heeling moment is applied to boats that use the WindFly Rig. The WindFly Rig can be mounted on a boat in such a way that leeway is eliminated. Boats using the WindFly Rig are able to plane upwind as well as downwind. The WindFly Rig can be fitted to commercially available 'off the shelf' boats in place of the outboard motor. The WindFly Rig takes approximately the same time to rig as a conventional sail rig.

In short, boats that use the WindFly Rig are:

- Fast
- Safe
- Practical
- Comfortable
- Fun

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No heeling moment is applied to the boat

The WindFly Rig ensures that the line of action of the force from the kite (or wing) acts directly though the centre of the keel. Therefore no heeling moment is applied to the boat.

• Ballast can be reduced or omitted - ... lighter boat, less resistance - ... for a lighter boat planing is practical for 'standard' yachts and dinghies, if they have a suitable hull form	• Faster • Much faster
• No wind induced heel - ... no heel resistance - ... better comfort	• Faster • More comfortable
• Less prone to knock down and capsize in heavy weather	• Safer
• A very large kite or wing may be used ... larger drive force	• Faster
• Narrower hulls are possible for displacement craft - ... less added resistance in waves - ... better motion with reduced pitch and roll due to waves and reduced slamming in heavy seas - ... improved self righting capabilities are possible	• Faster • More comfortable • Safer

No leeway

A combined 'keel-rudder' can be used to steer the boat and also resist the sideways component of the load from the kite or wing. There is no requirement for leeway of the entire vessel to generate lateral loads on a fixed centreboard or keel and so balance the sideways wind load: Leeway can be eliminated.

• The boat travels along the axis of the hull - ... more direct course - ... less resistance as no vortex shedding as the water flows across the hull	• Faster • Faster
• A deep V hull form can be adopted without increasing resistance due to vortex shedding as water flows across the hull - ... the deep V hull form reduces pounding in waves - ... a deep V hull form improves course keeping in heavy seas further contributing to a more direct course	• More comfortable • Faster

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Plane downwind, plane upwind

The drive force can be applied at approximately constant location and inclination relative to the hull. There is no difference in the operation of the WindFly Rig whether the boat is travelling downwind or upwind.

- Plane upwind as well as downwind
- Much faster

Fits to 'off the shelf' motor boat hulls

If the rig is appropriately proportioned the drive force may be applied at approximately the same location and inclination relative to the hull as the drive force applied by an outboard motor.

- Mount in place of the outboard motor on 'off the shelf' hulls
- Practical

Rigging time

- The WindFly Rig takes approximately the same time to rig as a conventional sail rig.

2. Theory

This section provides a summary of the principles underlying the WindFly Rig. Some simplifications have been made in the summary, a more rigorous analysis is provided in the documents available to download from www.WindFlyRig.com.

2.1 No heel

(successfully tested)

A short mast supports one end of the boom. The boom is free to rise and fall about the top of the mast. The mast is supported by a base unit which allows the mast (and the boom which it supports) to rotate around the longitudinal axis of the mast.

The kite lines pass three times between the base of the mast and the third point of the boom. From the third point the kite lines continue to the end of the boom and then to the kite.

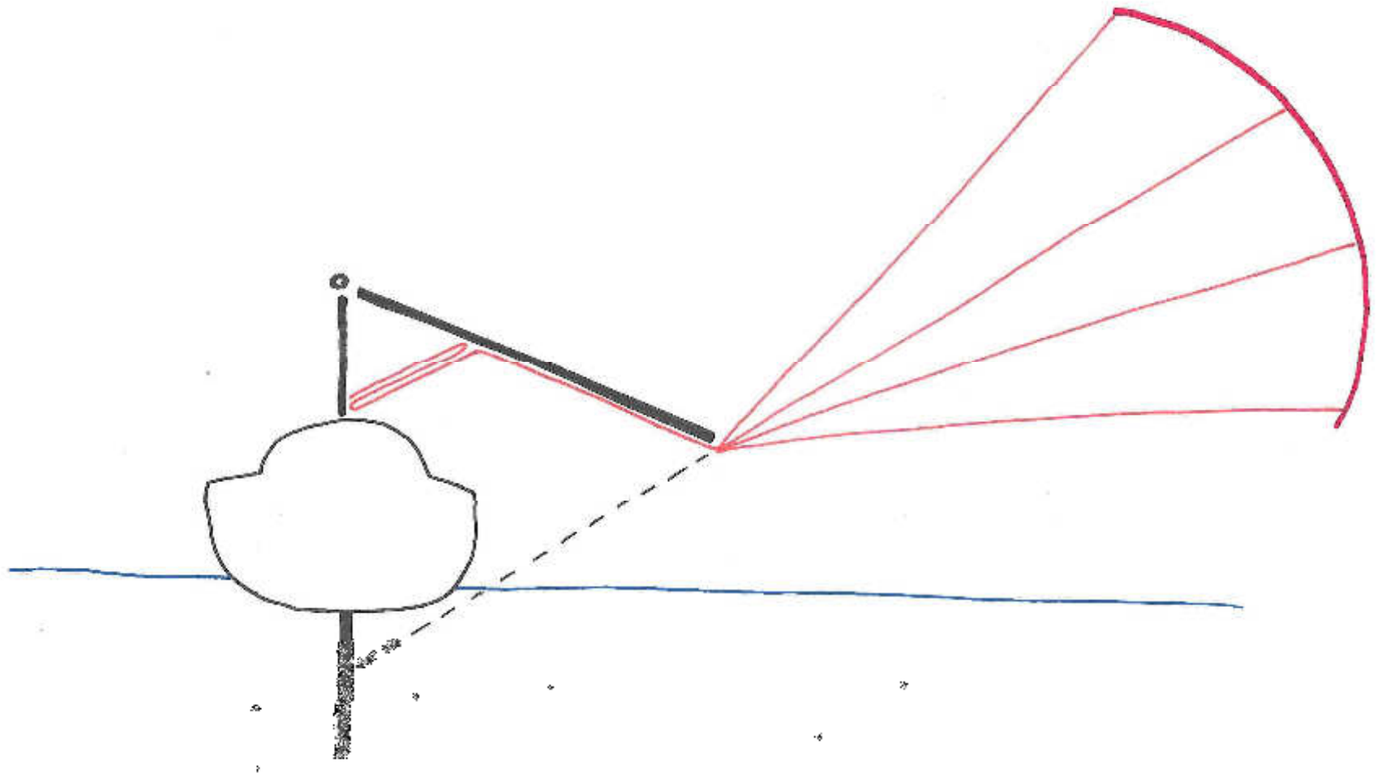
The lengths of the mast and boom are chosen so that two similar triangles formed by:

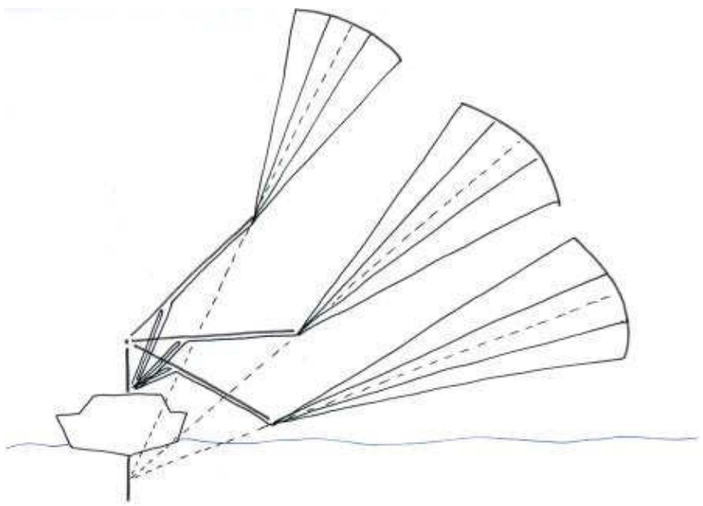
- The top of the mast, the bottom of the mast, and the third point of the boom, and
- The top of the mast, the centre of the keel, and the end of the boom

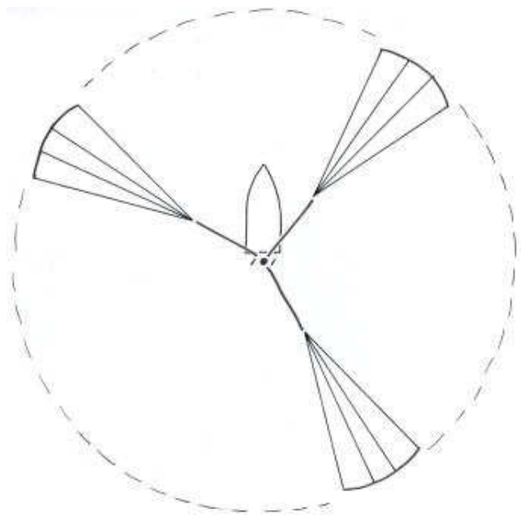
are similar triangles. Therefore the triple set of lines passing between the base of the mast and the third point of the boom are always parallel to the line passing from the centre of the keel to the end of the boom.

To maintain equilibrium of the boom, the triple set of lines passing between the base of the mast and the third point of the boom must be parallel to the lines passing from the end of the boom to the kite. The boom automatically rises and falls to maintain equilibrium as the kite moves. Therefore, the line of action of the kite lines always passes through the centre of the keel and, since the line of action of the kite lines always passes through the centre of the keel, no heeling moment is applied to the boat by the kite.

As the kite moves around the boat the mast and boom automatically rotate to track the kite so that the boom is always aligned towards the kite.







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2.2 No leeway
(successfully tested)

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.

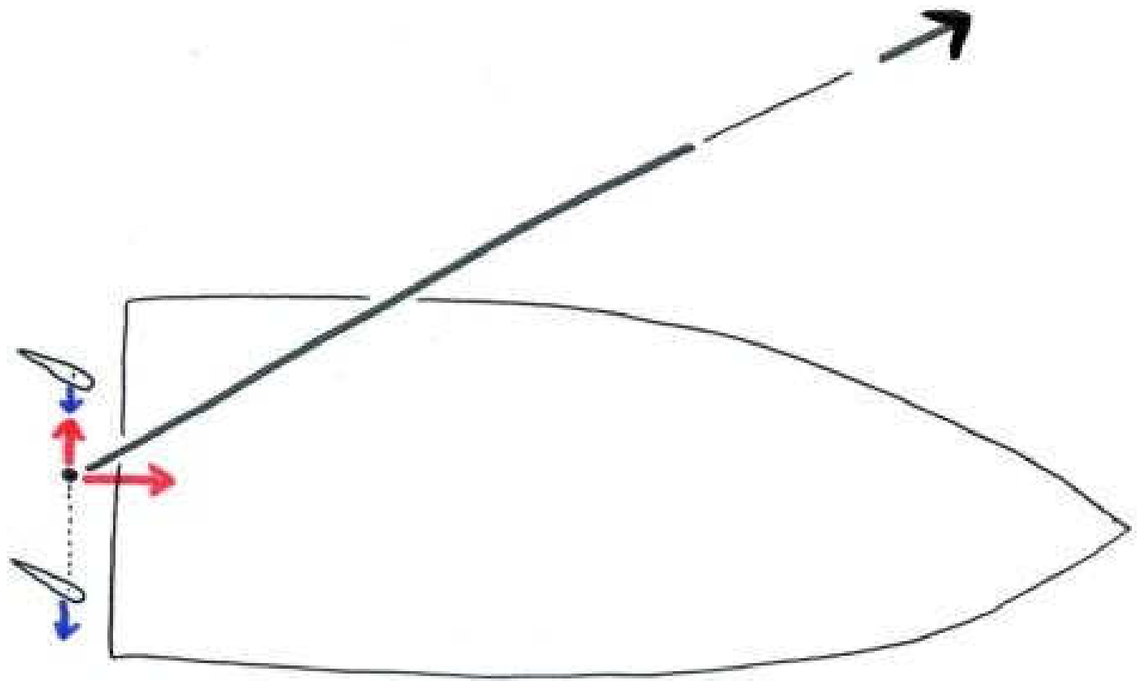
The centre of lift of a symmetrical foil is located 25% of the chord length behind the leading edge. If the WindFly Rig is mounted above the quarter point of the 'keel-rudder', the 'keel-rudder' rotates until the sideways force of the kite is balanced by the lift provided by the 'keel-rudder': the 'keel-rudder'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

Therefore leeway of the boat is not required to generate the lateral load to balance the sideways fore of the wind.

Of course this only works if the boat is moving fast enough for the 'keel-rudder' to generate enough lift to balance the kite load. 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 when the kite is likely to be flown at low elevation for sustained periods.

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.



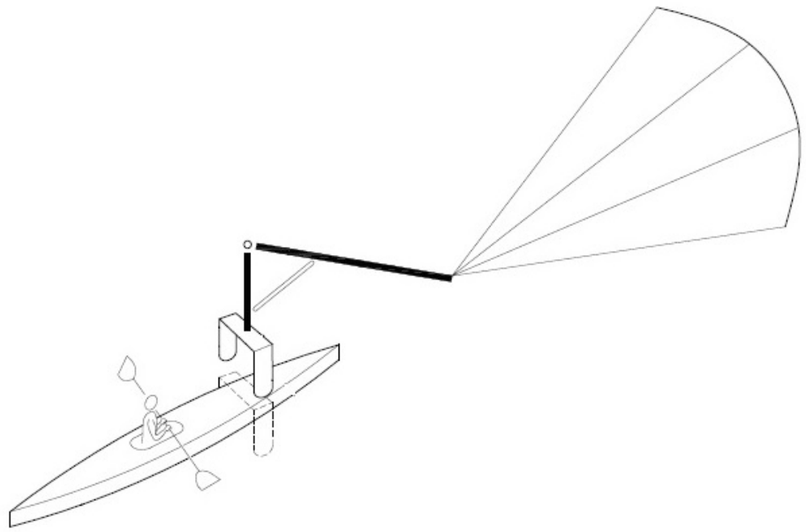
2.3 Placement of the WindFly Rig on the boat

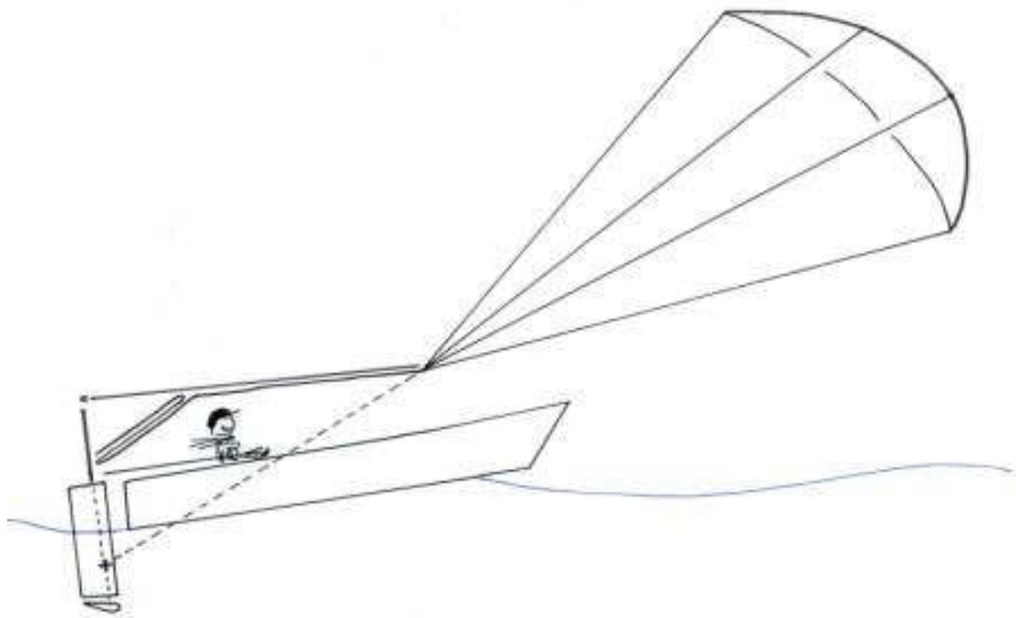
(successfully tested)

To avoid making the vessel turn, the WindFly Rig should be placed above the centre of lateral resistance.

For a displacement hull which pushes through the water the WindFly Rig may be located above a keel (or 'keel-rudder') which is placed anywhere along the length of the hull. It may be practical to place the WindFly Rig towards the bow to avoid complications when the speed is too low to provide steerage way.

For faster boats which plane (skim across the top of the water), the bow sometimes leaves the water surface. The WindFly Rig should be located so far back on the boat that the hull below the WindFly Rig never lifts clear of the water. This can be achieved by fixing the WindFly Rig to the stern of the boat, in the location where the outboard motor would traditionally be placed.





2.4 Planing - Part 1

(established theory)

Resistance on planing hulls falls very quickly as the Length Displacement Ratio[1] increases from 5.2 to 6.9.

A Length Displacement Ratio greater than 5.7 is generally considered desirable for a planing hull.

Using a traditional sail rig, it is very difficult to build standard yachts with a Length Displacement Ratio larger than about 5.2, therefore the vast majority of yachts are unable to plane reliably and are therefore unable to achieve speeds corresponding to a Froude number greater than around 0.45.

Due to the reduction in ballast, standard yachts using the WindFly Rig will typically have a Length Displacement Ratio in the range of 6 to 6.5. Yachts using the WindFly Rig are therefore able to plane reliably when there is sufficient wind.

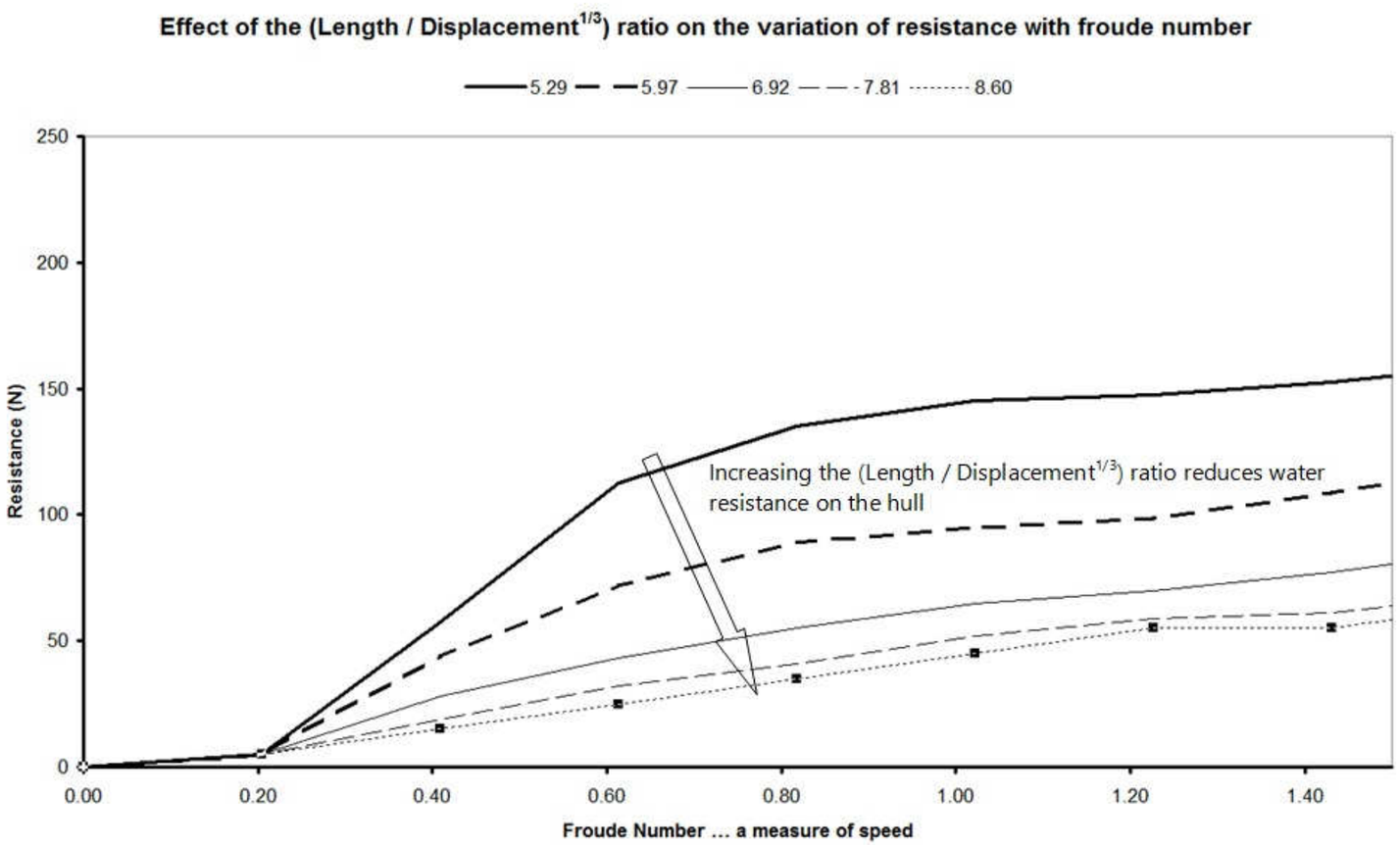


Chart is for hull type "series 62 single chine" with test data collected by Clement & Blount 1963
Other hull forms provide similar results

1. The Length Displacement Ratio is the water line length (m) divided by the cube root of the displacement (m^3).

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2.5 Planing - Part 2

(not yet tested)

When a boat is planing the hull skims over the top of the water instead of pushing through the water.

The trim of a planing boat is important. If the trim is too large or too small the performance of the boat is affected and it may not be possible to plane at all.

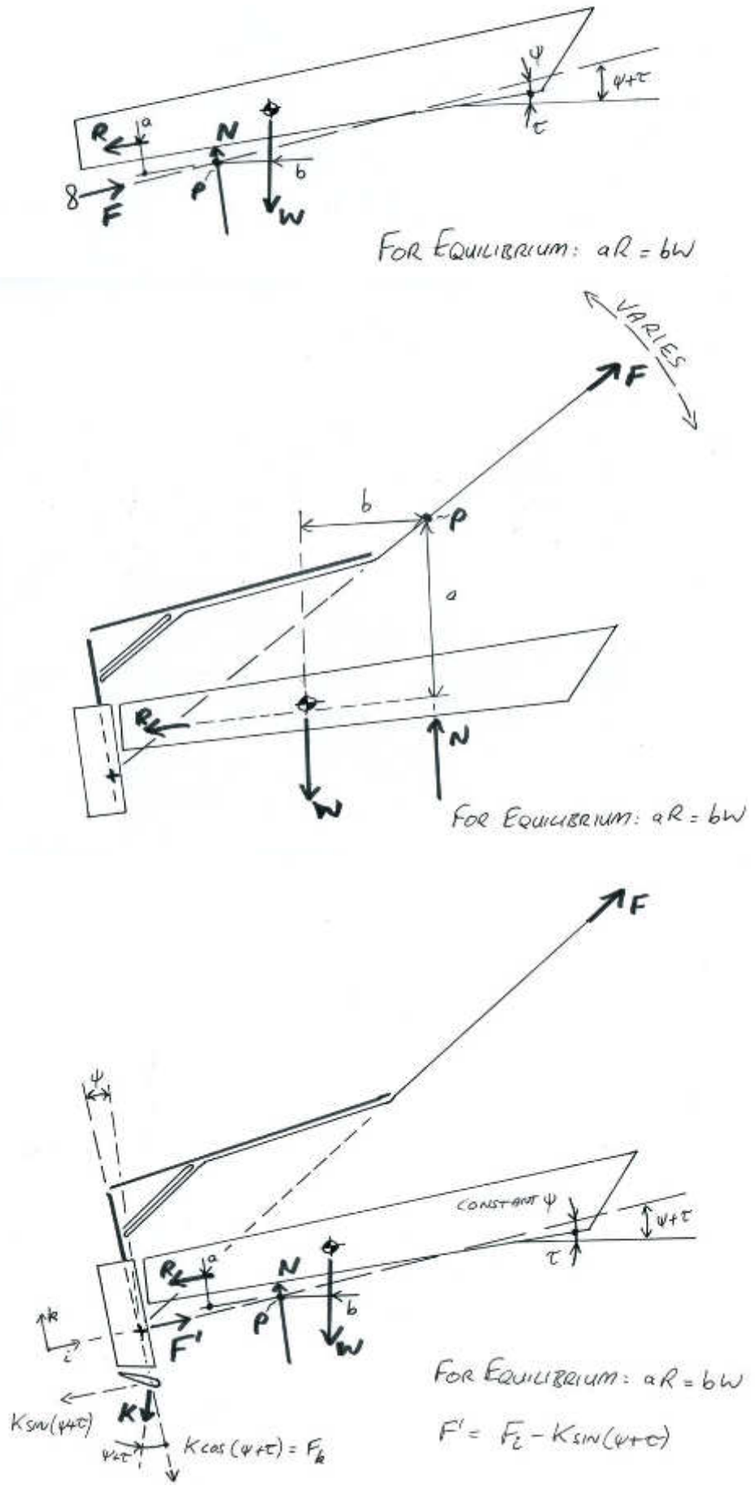
For a planing motor boat the trim is affected by the angle of the propeller shaft: if the propeller shaft is angled too high the bow is buried in the waves, and if the propeller shaft is angled too low the bow is raised high in the air.

The vertical component of the kite load makes it appear that the propeller shaft is angled very high. This has the effect of pushing the bow down and reducing the trim angle.

A hydrofoil can be placed below the WindFly Rig to offset the vertical component of the kite load.

The centre of lift of a symmetrical foil is located 25% of the chord length behind the leading edge. If the WindFly Rig is mounted above the quarter point of the hydrofoil the hydrofoil rotates until the vertical force of the kite is balanced by the downward force provided by the hydrofoil: the hydrofoil adjusts automatically to offset the vertical component of the kite load.

If the rig is appropriately proportioned the drive force is applied at the same point as the propeller load would be applied by an outboard motor. The WindFly Rig can therefore be mounted on any hull designed to take an outboard motor. The combined assembly of WindFly Rig, 'keel-rudder' and hydrofoil may be mounted in place of the outboard engine on commercially available 'off the shelf' boats.



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2.6 Kite control

(successfully tested)

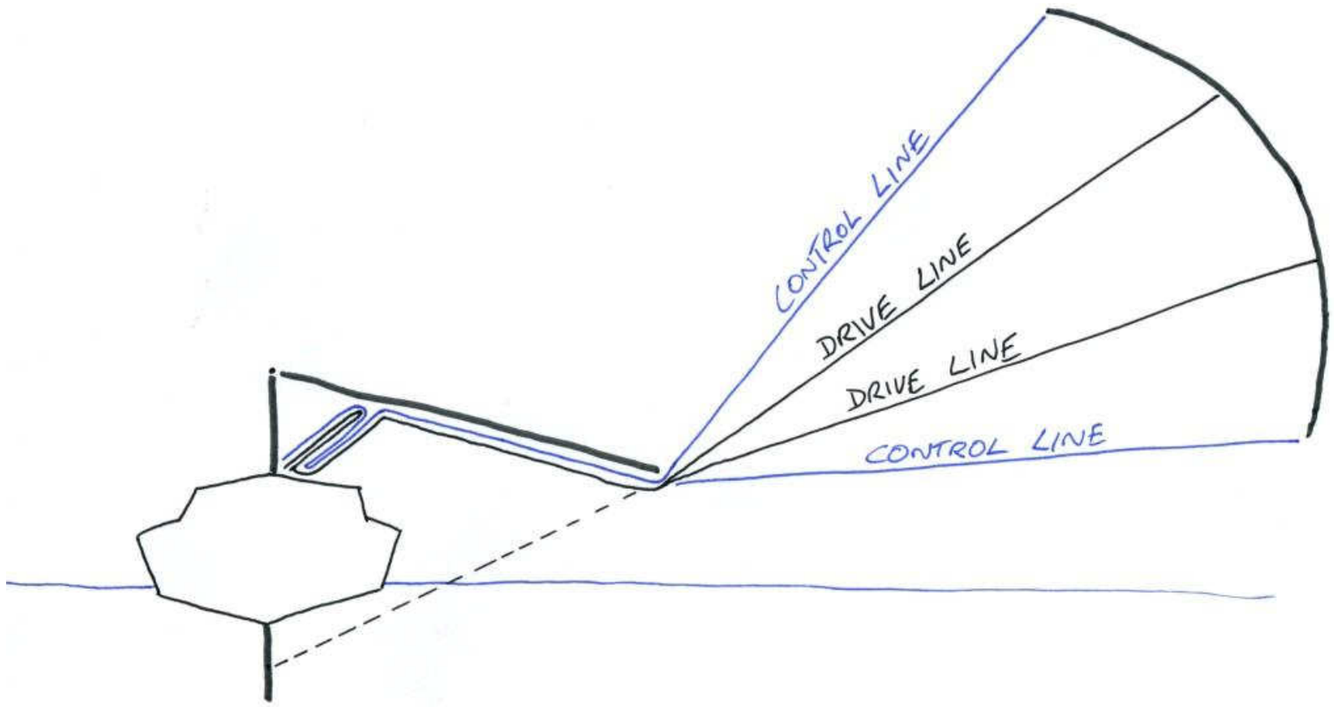
The majority of the kite load is carried by the central 'drive lines'. The two outer lines - 'control lines' - are lightly loaded and are used to steer the kite and adjust the power of the kite.

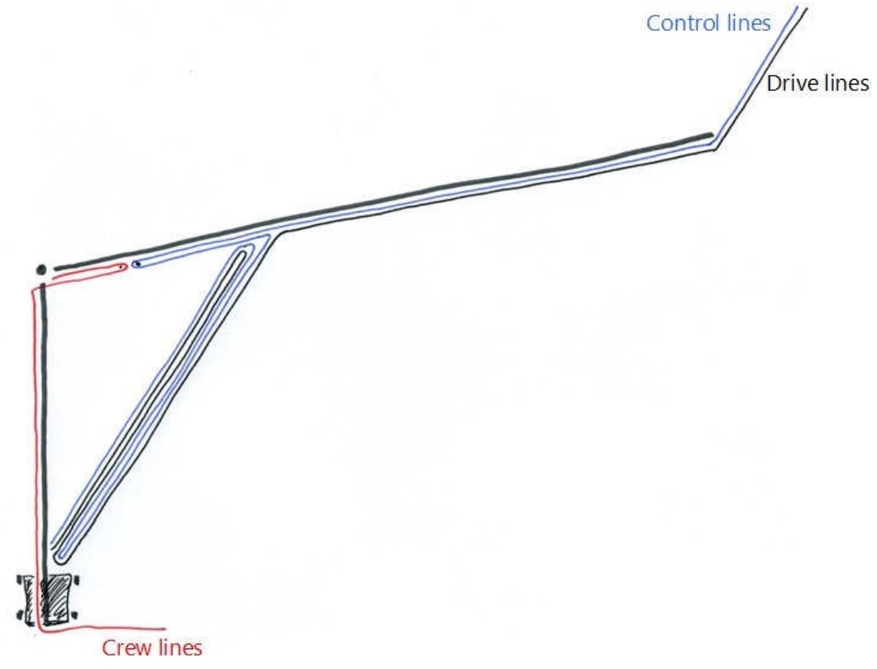
After passing three times between the third point of the boom and the base of the mast the 'drive lines' can stop at the base of the mast. The 'control lines' may continue through the mast base unit to the cockpit where the crew manually adjust the 'control lines' to control the kite.

Alternatively the 'control lines' may also terminate at the base of the mast. In this case the 'control lines' pass through pulleys on the boom and 'crew lines' connected to the pulleys pass through the mast base unit to the cockpit where the crew manually adjust the 'crew lines' to alter the length of the 'control lines' and so control the kite.

This arrangement allows the kite to be controlled as the length of the kite lines is altered.

The WindFly Rig rotates around the axis of the mast to follow the kite. The 'crew lies' - or the 'control lines' - may be passed over / under each other to avoid the lines becoming crossed as the mast rotates.





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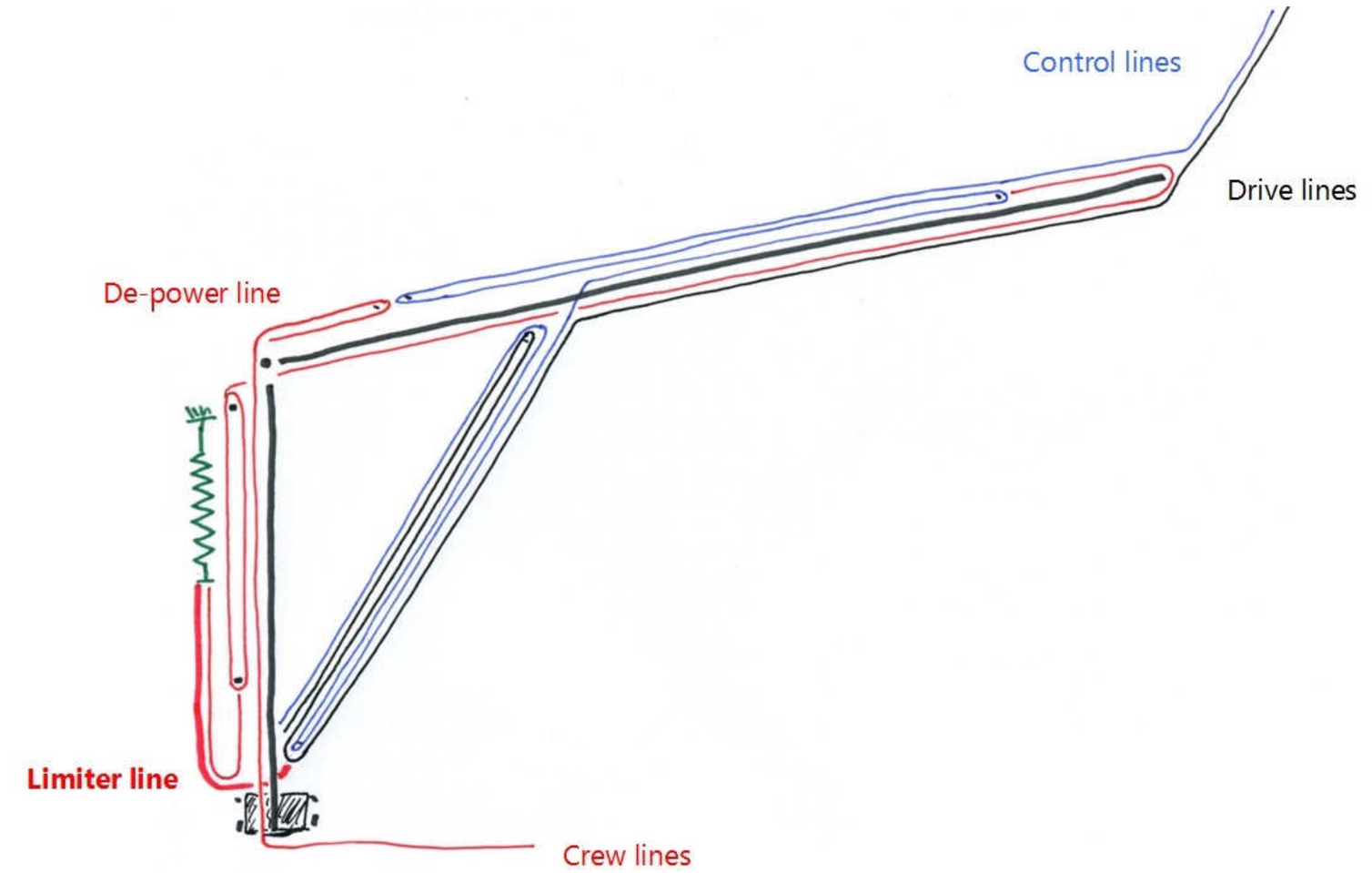
2.7 Load limiter

(successfully tested)

In gusts the wind speed increases causing a sudden increase in the load on wind powered drive elements – sailing boats are heeled over and may broach, kite boats are accelerated and may be lifted clear of the water. The effect is particularly applicable to kite boats: the airspeed and therefore the lift (drive force) vary as the kite is flown faster or slower, this effect may amplify a change in wind speed leading to an even greater increase in the drive force during a gust. In addition a kite may move quickly from the 'edge of the window' to the 'power zone' leading to a rapid and severe increase in the kite load. If the boat is lifted clear of the water it may not land upright, or may break up on impact with the water. It is impractical to design the kite, rigging, attachment system and boat strongly enough to take the potential increase in the kite load without breaking.

The WindFly Rig includes an arrangement that limits the maximum load which can be developed by the kite:

- As the kite lines pass three times between the third point of the boom and the base of the mast the lines pass around a pulley at the base of the mast.
- The pulley is held in place by a line which is connected to a spring. A traction gas spring is used so that the spring has zero extension up to the selected load and then extends rapidly if further load is applied.
- A 'load limiter line' is also connected to the spring. The 'load limiter line' passes through a pulley system to amplify the extension of the spring. The 'load limiter line' then continues up the mast and along the boom.
- At the end of the boom two pulleys are fixed to the end of the 'load limiter line'. The two 'control lines' pass through these pulleys.



When the selected maximum kite load is exceeded the spring extends. The 'load limiter line' therefore extends which moves the pulleys at the end of the boom. This increases the length of the 'control lines' and depowers the kite. This arrangement allows the control lines to be used to control the kite as the spring extends to depower the kite.

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2.8 Lines tensioner & storage

(tested, principles proved)

Kites do not fly reliably at low airspeed. Apart from when the wind is just not strong enough, there are various other occasions when low airspeed is encountered:

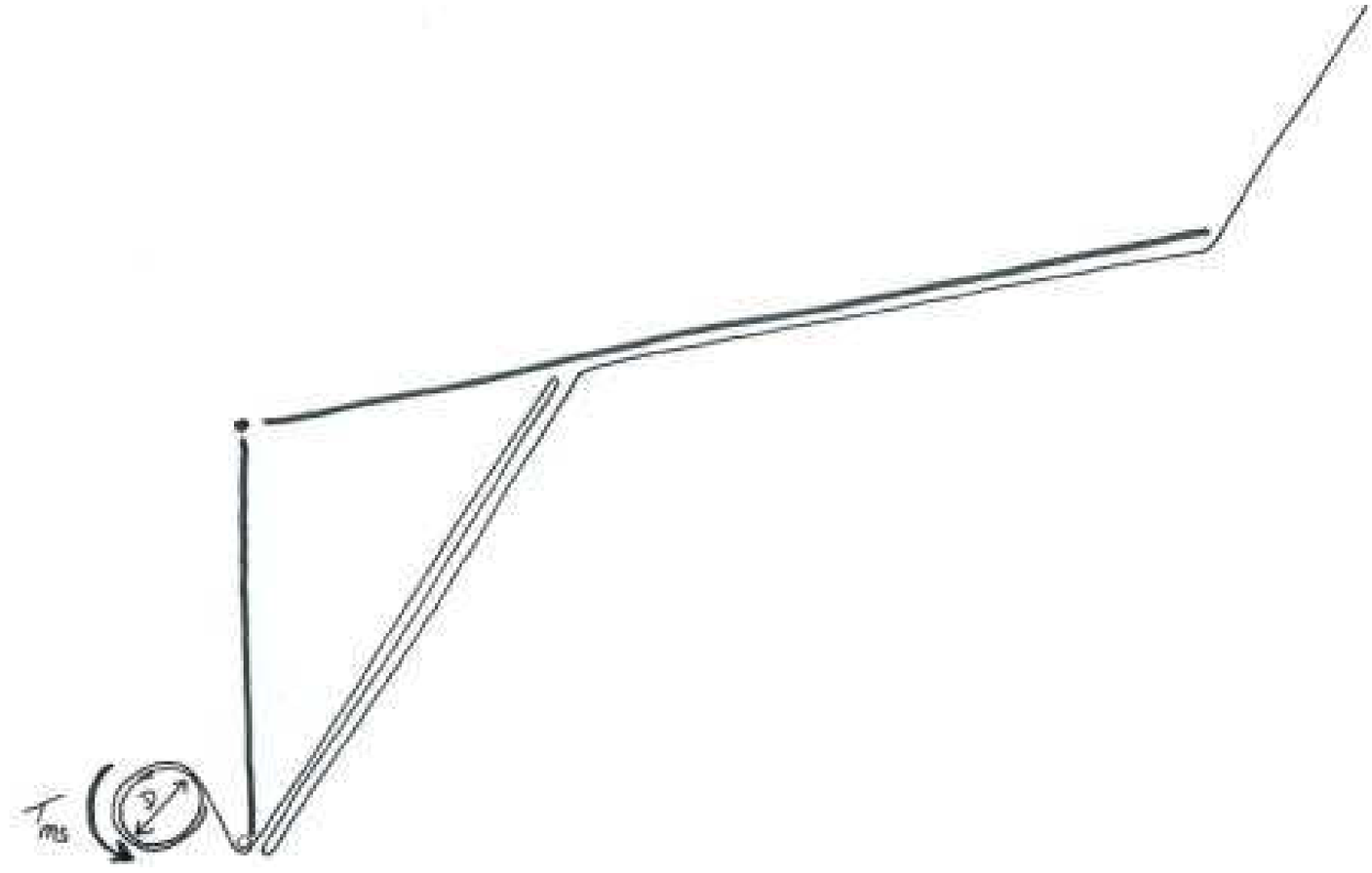
- When the kite is overflown it drifts back, stalled and windless, until it is can re-engage. This may happen even when the true wind speed is significantly greater than the minimum airspeed required.
- In downwind sailing the boat may over take the kite.
- When the wind is gusty there may be periods when the actual wind speed is less than the required minimum airspeed.

When the airspeed falls too low the kite lines go slack and it becomes impossible to control the kite.

The WindFly Rig includes a lines tensioner which avoids these problems:

- From the base of the mast the lines continue to a drum which is mounted on the rear side of the mast.
- The drum is connected to a motor spring which applies a constant torque to the drum.
- In normal use the kite load is sufficient to unwind the lines off the drum. However if the lines become slack the motor spring rotates the drum and draws the lines to maintain a minimum tension in the lines.
- The lines are paid out again once the kite is flying properly again.
- The drum provides a line storage system when the kite is not in use.

In conjunction with the arrangements for kite control and load limiting described above, this system allows the kite to be controlled using the crew lines as the kite lines are taken in and paid out. If a small kite is used a lock may be provided on the drum to prevent the lines being taken in when the kite load is small.



2.9 Automatic kite control

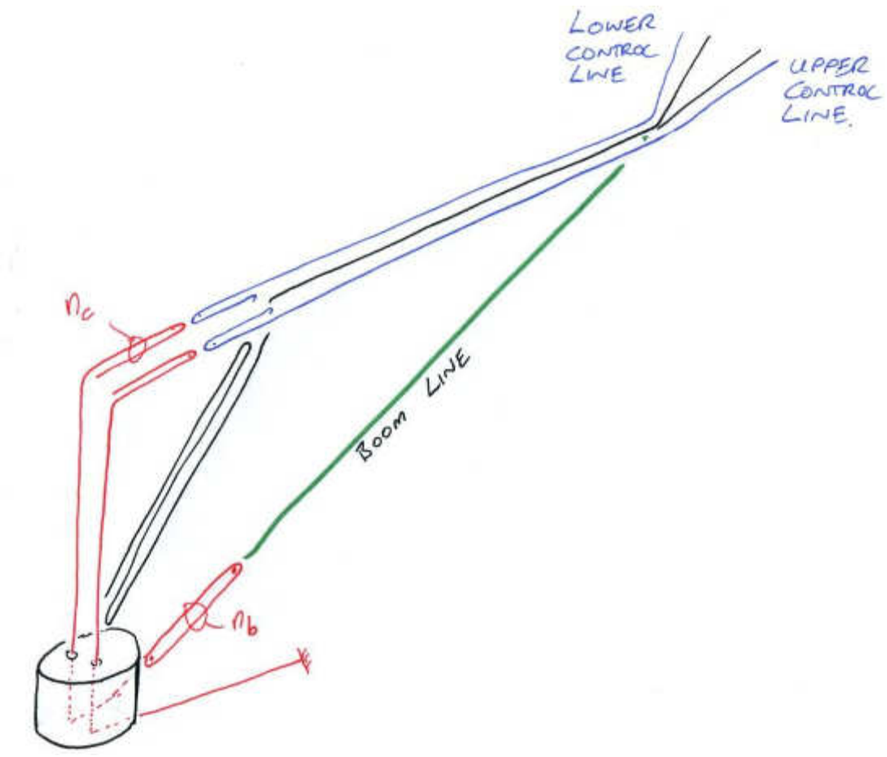
(not yet tested)

For automatic control of the kite the crew line running to the lower corner of the kite is connected to a boom line. The remaining crew line is set to a fixed length and therefore maintains the upper control line at constant length.

The boom line runs from the crew line to the free end of the boom. The lengths of the boom line and crew lines are set so that when the kite is at the target height and power the two control lines are of equal length.

If the kite descends below the target height the boom lowers. The boom line pays out the crew line and lengthens the lower control line. As a result the kite turns and climbs back towards the target height.

If the kite ascends above the target height the boom rises. The boom line pulls the crew line and shortens the lower control line. As a result the kite turns and descends back towards the target height.

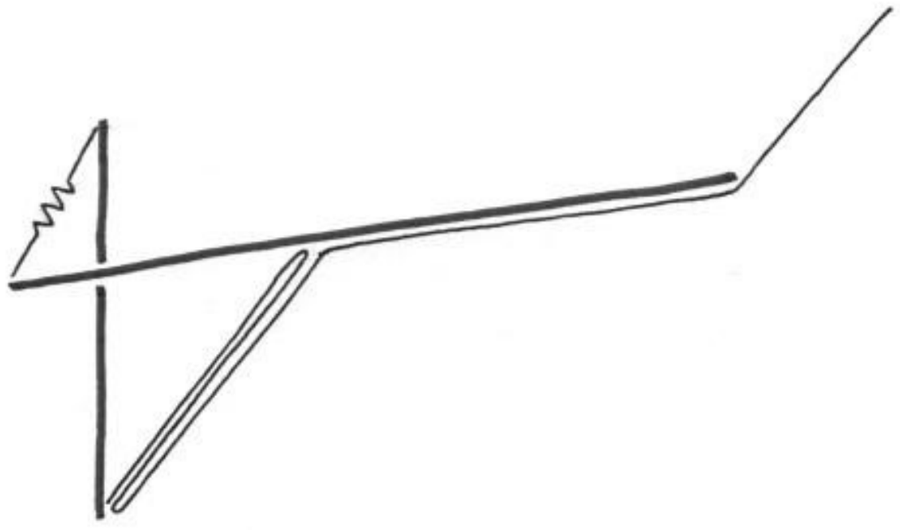


2.10 Offset boom self-weight

(successfully tested)

The self weight of the boom causes the boom to fall. The kite has to fly higher to lift the boom, this affects the alignment of the kite lines which causes the line of action of the kite lines to miss the centre of the keel which introduces a heeling moment.

The WindFly Rig includes a spring which balances the self weight of the boom. The spring allows the boom to operate as a spring balanced cantilever so that the kite lines do not have to support the boom: the alignment of the kite lines is therefore unaffected by the weight of the boom and the line of action of the kite lines always passes through the centre of the keel so that the boat does not heel.



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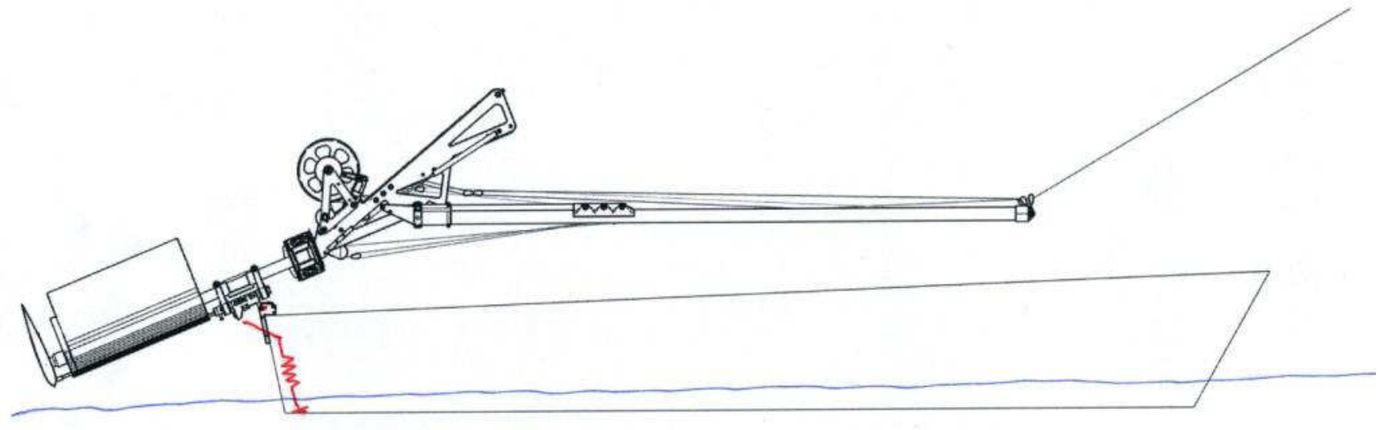
2.11 Raising the foils

(successfully tested)

The WindFly Rig pivots about the top transom mount - like an outboard - so that the foils can be raised to enter shallow water, or to keep the foils out of the water when the boat is not being used.

In normal use the forward drive force holds the rig upright with the foils in the water. A 'holding down line' is provided to hold the bottom transom mount tight against the transom: this allows the drive load to be reversed so that the kite can be used to pull the boat backwards.

The 'holding down line' passes around a pulley that is fixed to a spring: while the anchor line usually holds the rig vertical. If a large force is applied the spring extends allowing the rig to rotate so that the foils are raised out of the water. A traction gas spring is used so that the spring has zero extension up to the selected load and then extends rapidly if further load is applied.



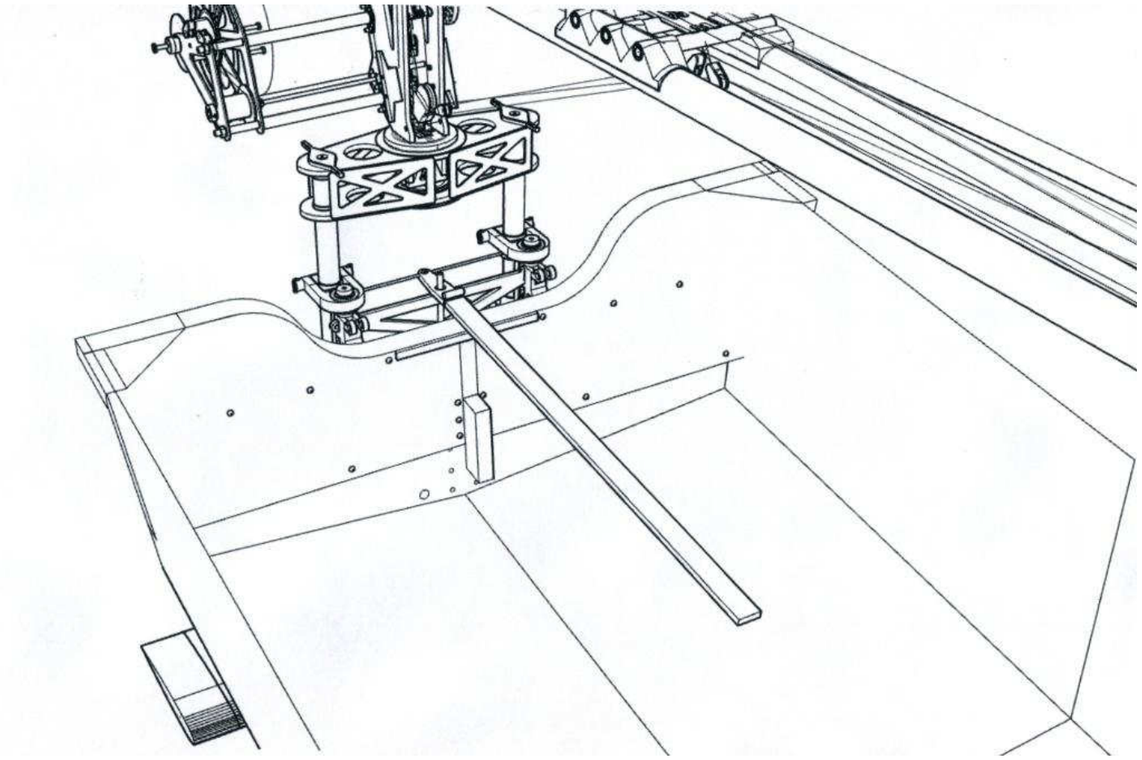
This arrangement allows the foils to be raised without releasing the 'holding down line'. The arrangement also allows the rig to rotate to raise the foils if an obstruction is hit, reducing the risk of damage to the foils.

2.12 Steering

(successfully tested)

A tiller can be used to steer the boat. The tiller pintle is placed at the midpoint of the line that connects the two '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, 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.

A hinge is included in the tiller on the boat side of the pintle. This allows the tiller to hinge as the rig rotates and the foils are lifted out of the water.



2.13 Quick release

(successfully tested)

Kite surfing equipment now includes an emergency quick release to allow the kite surfer to separate himself or herself from the kite. The same principle is adopted for the WindFly Rig, a quick release system allows the kite and WindFly Rig to be jettisoned in an emergency.

As with kitesurfing equipment a tiered release system is provided.

- If the 'crew lines' are released the kite is fully depowered. This will be sufficient in most emergency situations.
- A hook knife should be carried by the crew so that the lines can be cut to release the kite.
- Quick release brackets are provided at all points where the rig is connected to the boat. One handle is pulled to release all of the quick release brackets, this separates the kite and the WindFly Rig from the boat.

2.14 Self righting capability

(established theory)

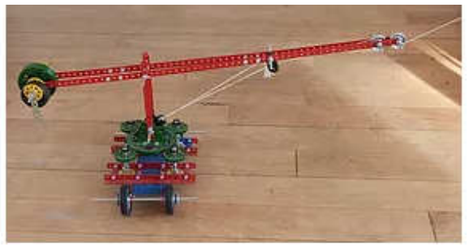
Since no heeling moment is applied to be boat a narrower hull can be used for displacement craft. This makes it easier to achieve a high angle of vanishing stability[1] and a small or zero negative area on the static stability curve, both of which improve the self righting capability.

1 The angle of vanishing stability is the maximum angle of roll from which the boat will return to upright in calm water.

3. Prototypes

This section summarises the prototypes which have been built and tested to date. Further details are available at www.WindFlyRig.com.

The WindFly Rig has been developed through a series of prototypes to the current version which is designed to be mounted in place of an outboard motor on standard 'off the shelf' planing motor boats. This version of the WindFly Rig is currently undergoing sea trials. Perhaps there has been too much focus on applying the WindFly Rig to a planing hull at the expense of achieving earlier success with displacement hulls.















- The WindFly Rig causes the kite to act as if the lines are connected to the centre of lateral resistance, eliminating heel.
- Use of a combined keel and rudder system which self adjusts to resist the sideways component of the kite load and eliminates leeway.
- The steering system that uses the same combined keel and rudder elements that are used to balance the sideways component of the kite load.
- The system for controlling the kite in a way that allows control to be maintained as the length of the kite lines is changed.
- The load limiter system which limits the maximum power of the kite - control of the kite is maintained as the kite is depowered.
- The system for raising the foils for access to shallow water
- The quick release system to immediately separate the boat from the kite and WindFly Rig in an emergency.
- The system for mounting the WindFly Rig on the transom of a commercially available 'off the shelf' hull in place of the outboard

The following has been tested and the principle successfully illustrated, however further development is required to achieve reliable operation:

- The system for maintaining a minimum tension in the kite lines, taking in and playing out the kite lines, and storing the kite lines.

The following have not yet been tested

- Operation of the hydrofoil to offset the vertical component of the kite load to achieve reliable planing.
- Automatic control of the kite.

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