Simplified Beam Mechanics for Anchored Airfoils

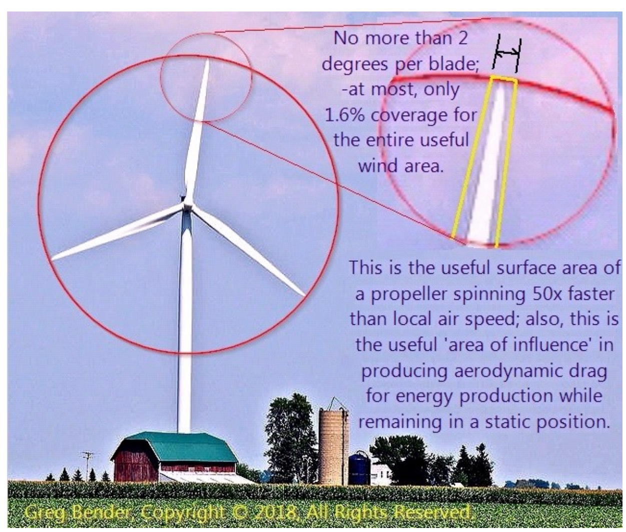
Propellers, Impellers, Wings, & Sails; The Different Aspect Ratios of the Reynolds Number

These four things have one thing in common, the Reynolds Number; but how they each benefit from it is completely different.

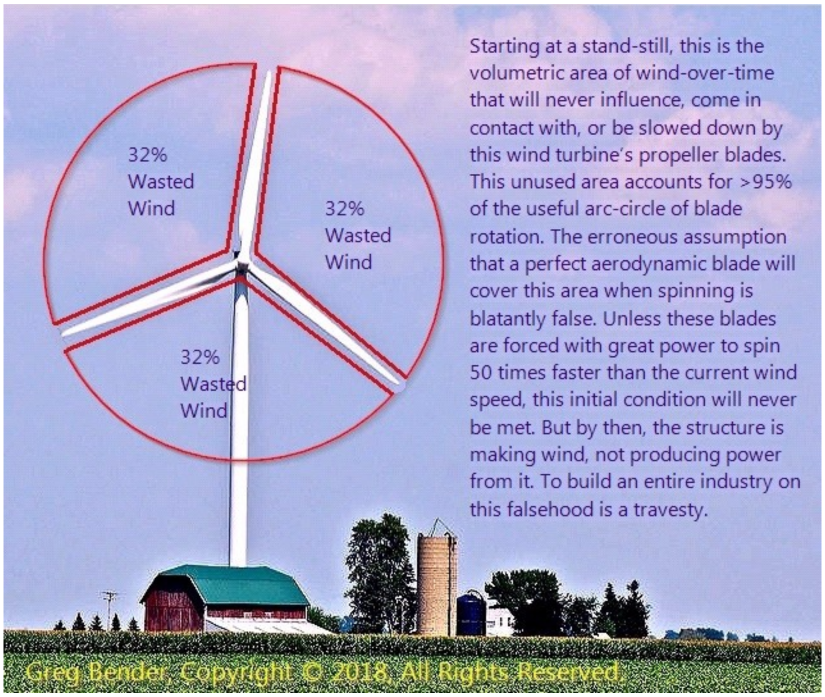
“The Reynolds number (Re) is an important dimensionless quantity in fluid mechanics used to help predict flow patterns in different fluid flow situations.” (Wikipedia) It represents a balance between fluid speeds and viscosities that are moving across a solid object with a given shape and cross-sectional length. Simplistically put: these are the balanced forces between Fluid Speed, Density, and Chord Length. And given an aspect ratio, the width of this Chord Length translates into a known Surface Area.

This is an important aspect because Air, at different speeds and pressures, transforms it’s viscosity from ‘thin air’ into something far denser, similar to water. This accounts for the change in wing shapes for super-sonic aircraft, which look more like short ‘fins’ than long airfoils.

It has been argued that Sails, with far more surface area, are more effective at low wind speeds for collecting wind power. The propeller-based designs for modern Wind Turbines have extreme length-to-width aspect ratios covering a very small amount of total frontal area, leaving large gaps in coverage over the whole rotational area.



Most of the design equations for Blade Solidity are set around Impellers, specifically hydro-generators. The density of Water is still much higher than compressed air at super-sonic speeds, so the H/W aspect ratio must be very much less for keeping a minimum beam-tip deflection while under full pressure. More importantly, the rotating surface areas of the Impeller Blades take up the maximum volume within the Impeller Chamber; -any gaps are kept to <1/100" minimum.



This is in complete contrast to free-air Wind Turbines that have no containment chamber, duct, or fairing of any kind; and start out with a 96% air gap between blades at a stand-still. These extreme length-to-base ratios of these wind turbine blades suggest that they can barely hold their own weight, much less any wind loading.

Wings on airplanes are generally as light as the fuselage they are attached to, so both move in unison with distributed weight and wind loading. A wing attached to an airplane is not considered an "anchored airfoil" because the mass of the attached inertial body/fuselage does not exceed the exerted mass of the airfoil-wind-loading by more than ten times. If it did, (assuming the plane could get off the ground), an airplane with this loading would snap in half at the slightest down-draft. These anchored conditions happen with direct-drive hydraulic Impellers and Sailboats; and both are pushing against the incompressible mass of Water, where Density in the Reynolds Number plays the significant role.

The initial conditions for Sails are different from Impellers and Wind Turbines for many reasons. To begin with, Sails are not confined to the strict dimensions of a turbo-chamber. Sails, by design, can be maneuvered over a large range of Angles-of-Attack, thereby managing many lateral forces and maximizing lift for varying wind directions and conditions.

To get Sails to work effectively in Wind Power, one must re-think how to build a Mast, not a Propeller; -something the Wind Industry apparently doesn't understand yet.

It is important to note: Sails are not subject to Gravity; neither are Wind Turbines in producing power. This fact alone changes many of the initial assumptions between driving airfoils-for-airplanes and using land-based anchored airfoils for producing energy passively. In other words, airfoils-for-airplanes still have to be driven forward with enough energy to produce enough wind speed to provide enough lift to stay up.

On the other hand, Wind Turbines always start at zero speed, and must absorb energy backwards at low negative pressures. This concept is seemingly counterintuitive to Propeller Designers because this condition is at the other end of the Reynolds Spectrum in terms of low negative air-speed vs. chord-length.

Anchored Airfoils and Simple Beam Mechanics

The following four diagrams represent the basics of Anchored Airfoils, and illustrate four cross-functional concepts at once:

1. Simplified Cantilevers and Fixed Beam Physics,

2. The varying height-to-base ratios of an anchored airfoils that change relative to the angles-of-attack, and the resulting aerodynamic lifting forces,

3. The significant differences in design and usage between Impellors, Propellers, and Sails,

4. The oblique angles of forces that are useful with Sails, but either stall or become catastrophic with Wings, Impellers, and Propellers.

Keep in mind, there is only one narrow set of angles that work for a Propeller, there are three basic incident air flow conditions for an Airfoil Wing, and five viable wind angles for basic Sails, This takes into consideration that a Sail is an anchored airfoil moving a mass very much larger than the wind loading of the Sail itself.

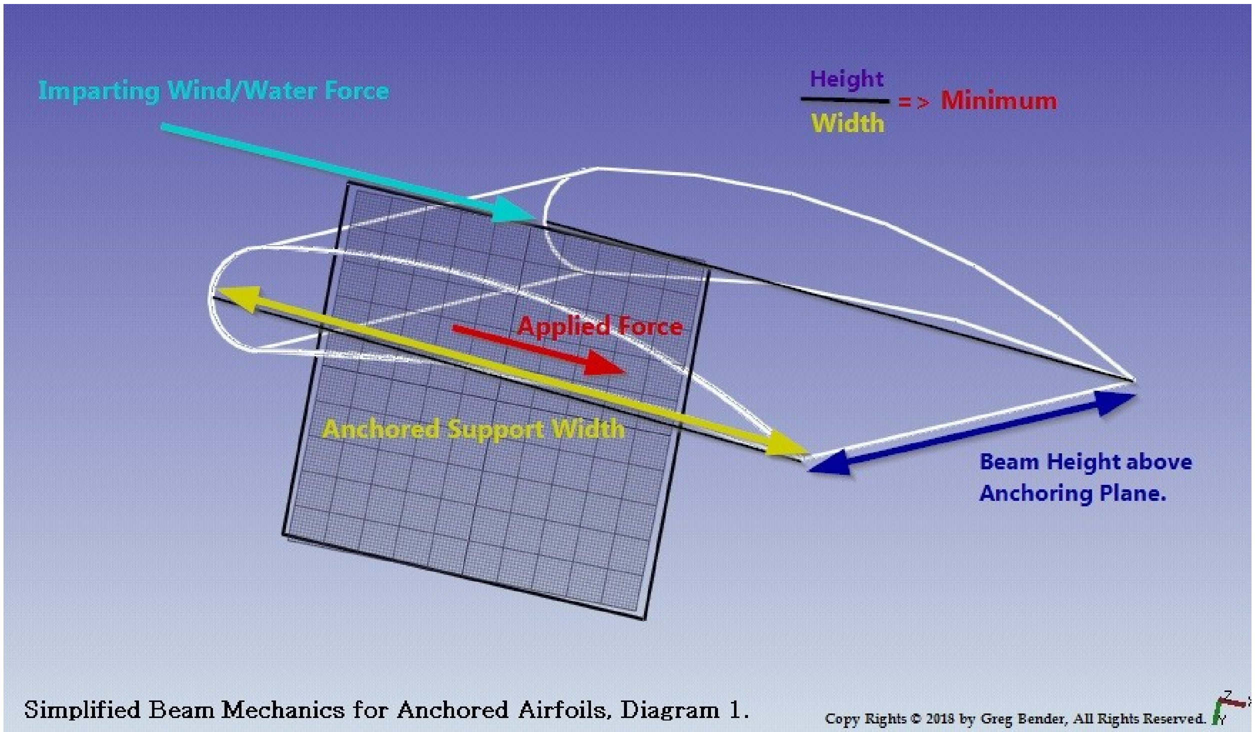


Diagram 1. Minimum Force, Maximum Support. No lift for airplanes; and a full stall, -or a full Luff, for sailboats, (also known as being in "irons").

Diagram 1 is reference point Zero, where the incident wind/water angle is flat and parallel to the wing/blade chord, and there are no imparted lift forces in either direction. With the least amount of applied forces in this position, the blade has the strongest base-to-height ratio,

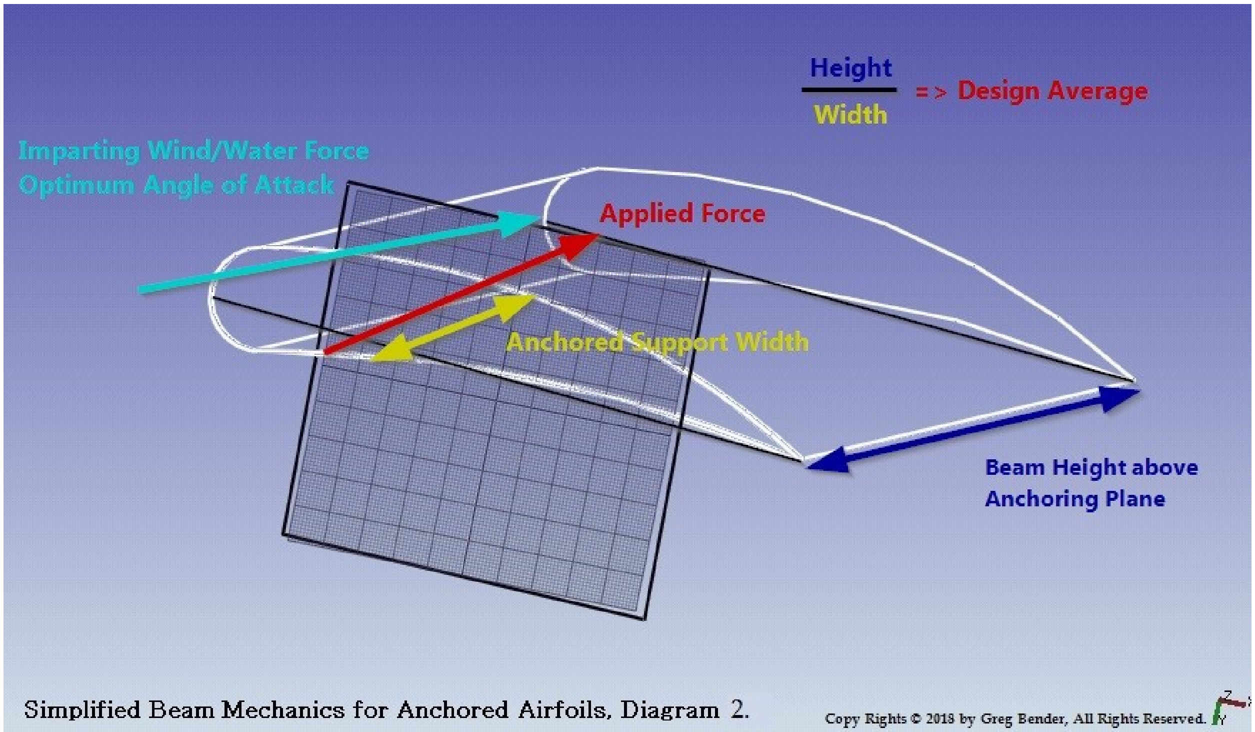


Diagram 2. The Optimum Lifting Angles for airplane wings are considered "Tacking" angles in Sailboat racing.

Different than airplane wings, the best angles-of attack for Sails come within reach of 40 degrees of the head-on wind direction. The extra 22 degrees of lift beyond what airplane wings could climb at, is needed by the Center Board below in the water, which is providing the hydrodynamic counter forces to the Sail. In effect, The Sail is using passive wind power to achieve enough lift to move 45-50 degrees *into* the incident wind direction.

Gravity is the counter force with airplanes, and it sets the glide-ratio very seriously. Airplanes always need an applied force to stay aloft. Sailboats simply need to float and apply two lift forces against each other to move forward. The aerodynamic forces between the Sail and Hydrodynamic Blade below must match. Balancing these two "wings" at different ends of the Density Spectrum in the Reynolds Number requires an appropriate shift in Surface Areas between the Sail and the Centerboard.

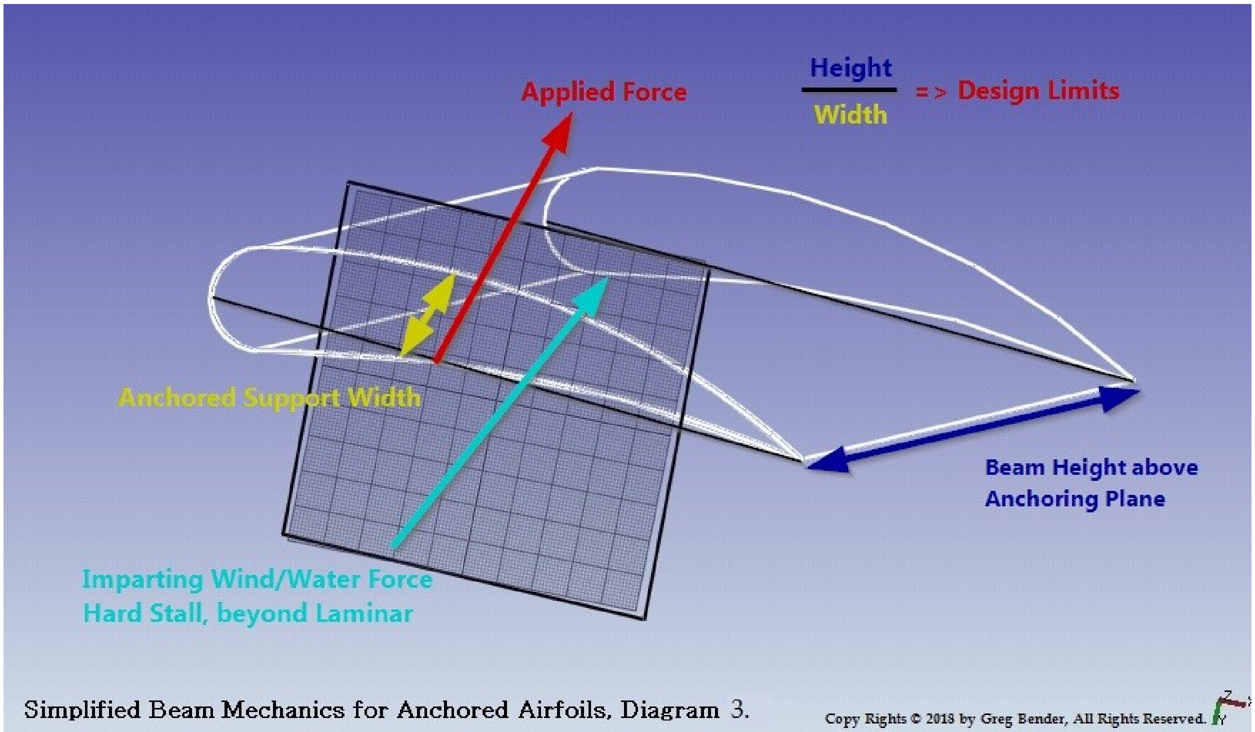


Diagram 3. These angles are well beyond catastrophic Gravity-Based Stalls for airplanes, but the "Reach" and the "Far Reach" are the fastest Sail Angles for racing.

When the incident angle-of-attack of air flow reaches beyond 65 and up past 90 degrees to the hull, -angles that would be catastrophic for airplanes wings and propellers; Sails become the most effective in pulling power out of the wind. When both the wind direction and the hydrodynamic centerboard blade forces are working against 90 degrees, the Sail splits the reflective difference at 45 degrees and picks up the maximum amount of power in three ways.

1. Air Compression, -capturing a large cross section of wind at 45 degrees, the Sail slows down about half of that air-mass-momentum creating a backpressure on the incident air mass coming in, raising the local air pressure inside the Sail,
2. Air Mass Re-Direction, -also with the Sail at 45 degrees, about half of the incident air flow mass is directed 90 degrees, under ideal conditions. The Sail captures the energy of forcing this air-mass-momentum sideways, thus producing a great deal of directed thrust forward.
3. Massive Pressure Differentials, -unlike airplane wings which achieve a modest 3-5% pressure differential top-to-bottom within a small range of angles-of-attack, Sails create massive pressure differentials on the order of several Atmospheres. In some conditions, Sails can pull a vacuum on the 'back-side' of the Sail, creating more far more pressure-per-ft2 than ever possible with Wings, Propellers, and/or Impellers.

These three conditions will pull the maximum amount of energy out of the wind by slowing it down and diverting it as much as possible; but only by using very large cord lengths and surface areas. This large-area aspect ratio is inherent with Sails, which are light weight in construction, and are far more economical to make & install than carbon-fiber propeller blades.

Under certain conditions, such as Ice Boat Sailing, when the forward friction is low enough, these Ice-skating Sailboats can move several times faster than the wind. This is truly an exhilarating experience. More importantly, these are the specific sail angles that will produce the most amount of wind power in Sail Turbines.

This aerodynamic fact is in complete contrast, and completely counter-intuitive to anything being taught in Wing Aeronautics, Propeller, or Impeller Design. And, it is this very specific misunderstanding that is at the root of the entire Wind Power Sector, which is keeping them limited to <3% for generating renewable energy, industry wide.

It is important to understand the significance that chord length and surface area have within the Reynolds Number for pulling vast amounts of power from large masses of slowly moving air.

Sails are not designed to slip through the wind like Wings; they are designed slow it down and pull as much power out as possible. Sails are designed to create as much Drag as possible. That is how to get real power out of wind power; ***slow it down and divert it.*** These are the same principles applied to Impellers. Why can't Wind Industry recognize the same with Wind Power?

Typical Wind Turbines are not going to slow down and divert any decent amount of wind with those spindly propeller blades and a 96% air gap between them.

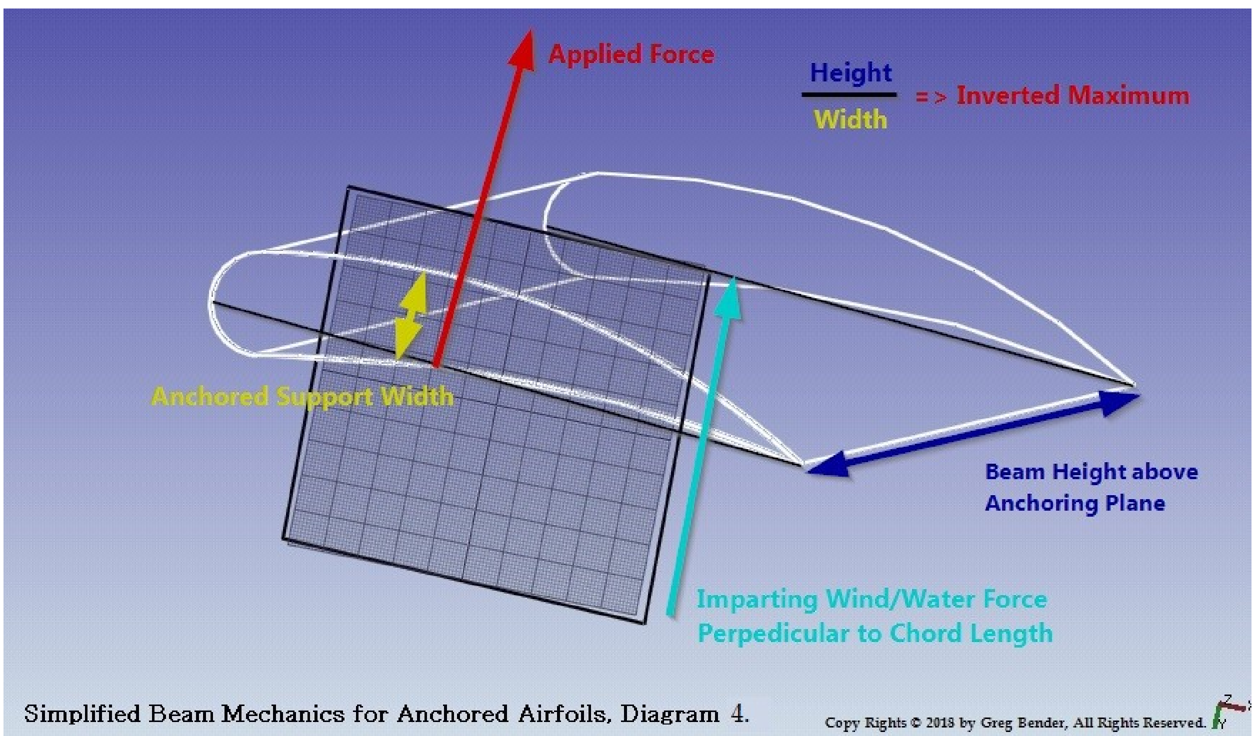


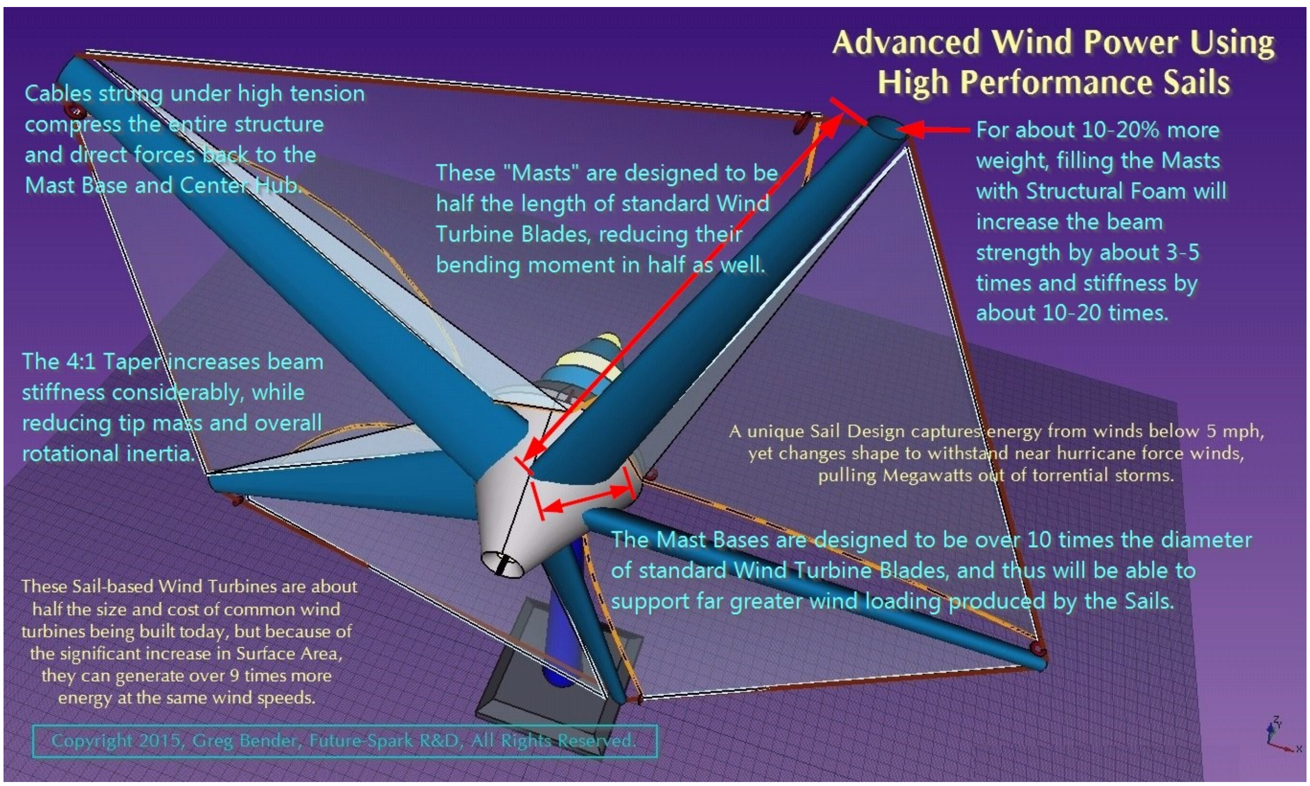
Diagram 4. This perpendicular wind loading is a "Full Run" for any Sailboat, yet catastrophic for most other fixed-wing aircraft and anchored aerodynamic and hydrodynamic foils. Sailboats often apply a 'Spinnaker' to increase these specific lateral forces. Nonetheless, with these Normal, or Perpendicular Forces at maximum, the sail, and the boat, will never exceed the speed of the wind.

The Sailing Industry, for the last several 100 years, has made good use of a 6 inch-wide Mast, making it solid enough to handle the massive wind-loading of sails, -which is over 30 times the lateral forces that typical spindly propellers blades could handle.

The Sailing Industry has known for many centuries how to handle these lateral forces produced by 45-90 degree angles-of-attack to get the most power out of the wind; yet this is something that is unheard of in the Aeronautics and Wind Power Industries. This idea would appear as an unspeakable failure in design. Yet, this is exactly where to get the most power out of the Wind.

Again, the focus is on how to make a Mast, not a propeller blade; the Sail does all the work.

These salient features illustrated below will demonstrate how to handle Mast Solidity for Sails. These are some of the new parameters that are needed in working with Sail Turbine Designs. The combination of these key structural features will supersede the solidity and strength of any spindly propeller design by a significant order of magnitude, or two.



By increasing overall surface area using lightweight Sails, the total output from the Wind Power Sector can be increased over ten times; thus providing closer to a third of all Renewable Energy.

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