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HyperTurbine, a Wind Machine From Another World[1]

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ABSTRACT

The wind power mindset has lately been substantially affected by the confrontation between expectations and reality. It has been systematically shown that in practice the amounts of energy produced are much smaller than what seemed to be calculated by technicians who strongly promoted such an idea. We have to say we feel deluded too. The problem has to do with the lack of a clear interpretation of what wind speed means, in practice, in terms of available energy, and also the lack of analysis of the transference of energy along all the parts of the wind system, including its electrical components. A final observation that inverters operate on a basis of 50% efficiency when transferring power, in effect reduces the performance of a wind system claimed to be 30% efficient as half of this. This led us to estimate that most wind systems would be operating with no more than around 15% efficiency, which is a poor figure, specially for small wind turbines. The other aspect is to realize that systems in the market are rated at wind speeds around 10m/s, which in effect means "strong wind", therefore for situations occurring infrequently, in most places. Nevertheless, here we present our latest conception of a wind turbine, which we decided to name *hyperturbine* due to the fact that it is based on a completely new strategy for collecting the wind energy, and on a design we consider even more interesting that the *superturbine* proposed in a previous article.

1. Introduction

We found "*a wind machine from another world*" a humoristic title for presenting the unusual method for capturing energy from the wind described presently. It is a case of unusual symmetry. Circular symmetry, normally used for this purpose, both in horizontal axis turbines and in the vertical ones, naturally led people to accept as almost natural collecting the wind impulse by means of some radial element repeating itself around a circle (the blades). Although the same circular symmetry is in effect used in this novel design, we decided to use it in a way that would optimise the amount of 'wind-particles' collected from wind, while minimizing the drag effects opposing the rotation of the machine. Our thoughts are based on a particle-like approach, not on a fluid-like approach. We have not yet even thought about blades. Although such an approach may seem too imprecise for modelling the dynamics of a wind system under high speed winds and fast rotation of the blades, we are in fact interested in the opposite: slow rotation of the machine, and that the system stalls at high speed winds. The first, will ensure the transference of a good torque to the generator; the second will make the turbine seem a 'wall' to the fluid in the circumstance of a storm.

In the following sections we try to explain the ideas behind this new design and present some images captured from a 3D modeller. Although we have built a first scale model of this machine, and observed in practice how easily it runs even at very low wind speeds, no other prototype has yet been constructed in order to fully characterize the machine. It would be interesting if someone would

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[1] It is the author's wish that the ideas and systems presented in this article will be considered *anti-patent*. This means anyone has the right to use them or replicate any of the described systems for free, without the need for any special permission. If used for business, however, those interested have the duty of contacting the author in order to obtain such a permission and to negotiate the appropriate compensation.

finance us to build a real machine based on these concepts.

2. Wind force, drag, lift, resistance to rotation

Wind turbine design is usually a complex process of calculus taking into account the effects of the interaction between an incompressible fluid flow and a solid structure. These are expressed by the *Navier-Stokes* equation, which relates the various sources of force and returns a distribution of velocity. Although this is an excellent method to estimate the resulting flow of the wind in certain situations, we believe that it is mostly appropriate as an optimization tool, and not as a fundamental tool. In our point of view, the fundamental interactions can be simply understood and described based on the universal principles of *energy-conservation* and *momentum-conservation*, and looking at the wind as being a huge field of little *wind-particles*. Lift, a typical effect from a solid moving through a fluid, can also be imagined if we think of all those little *wind-particles* as linked to each other by a force of cohesion. The most important analysis of a turbine design may therefore relate the force of the wind with the energy captured by the machine, which highly depends on the drag and lift effects. A fair 3D preview of these effects will of course help a lot. The next figure shows the basic effects considered in a wind turbine design, which is frequently reduced to the design of its blades.

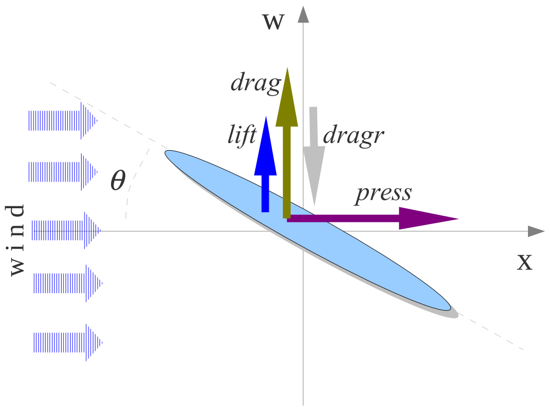


Fig. 1 Basic effects in a blade of a wind system.

Notice that '*x*' represents the direction of the incoming wind, while '*w*' points to the instantaneous direction of rotation, which somehow can be seen as a 'circular' direction. The machine rotates along this direction. The arrows shown in the figure represent the main reaction forces to the impact of the wind in the blade. Notice that *drag* and *lift* are responsible for inducing torque in the machine, while *dragr*, the force produced by the resistance of air against the blade when it rotates, is in fact the main source of resistance to its movement, acting therefore as an anti-torque effect. Usually, the blade design is optimized in order to find the best possible ratio between *lift* and *drag*. The force we named *press* is simply the pressure imposed on the blade in the direction of its flow. It contains the direct pressure of the wind in the blade and also the projection of the original *lift* (which in fact is perpendicular to the blade surface) in the '*x*' direction, usually called *induced drag,* in aeronautics. The rigidity of the turbine, and also of the structure of the machine, must be able to support this force even in the worst conditions of operation.

As we see, to handle these effects together is not an easy job, and in general one should not expect optimal solutions, since they even depend on several other aspects that are not easily controllable, like wind speed, turbine radius, etc., but also the price of the materials and the feasibility of the technological solutions. There are, however, in our opinion, some directives that might be followed in order to produce a good wind machine. The idea is: maximize torque, minimize resistance to rotation, maximise resistance to storms.

3. The blade design

Once the previous concepts are well understood, the blade design process can start. As we know, *lift* is stronger than *drag* for small wind speeds and small angles of attack (θ), showing a maximum around $\theta = 20°$. Small angles of attack, however, imply that *dragr* will tend to be high, since it has its maximum at $\theta = 0°$ and its minimum at $\theta = 90°$. On the other hand, the *drag* effect will have a minimum at $\theta = 0°$, a maximum at around $\theta = 45°$, and again a minimum at $\theta = 90°$. Finally, *press* will exhibit a minimum at $\theta = 0°$ and a maximum at $\theta = 90°$. The problem of an airplane wing is usually a problem of maximizing *lift* while minimizing *press*. The problem of a wind turbine blade is more complex. So, what to decide?

Suppose we first want a drag machine, that is, a machine in which its torque is mainly induced by the *drag* force, with no *lift* effect. Let us start with the simplest blade design, a rectangle of a very thin material, as shown in the next figure, with an angle of attack of 45°. Notice that the blade rotates to the left, and the '*r*' axis points in the direction of increasing turbine radius.

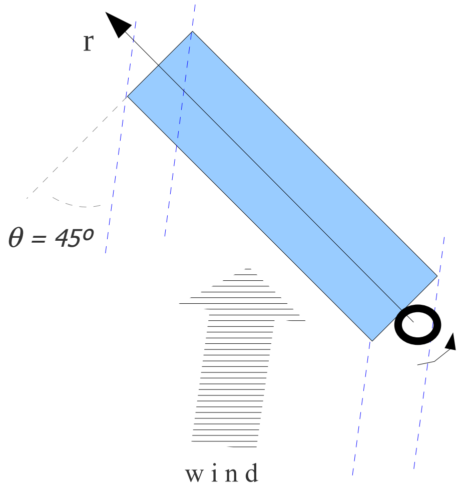


Fig. 2 Wind attacking a rectangle with $\theta = 45^\circ$.

Considering the wind force homogeneous, the torque induced in the blade by the wind flow comes from *drag* effect, which is constant along the '*r*' direction. This would be the only contribution to the torque if the the blade would be stopped. However, if we consider that the blade tends to rotate with an angular speed ω due to this effect, we must also consider that there will be resistive forces contrary to the rotation applied to the blade. These are what we called the anti-torque forces, due to the *dragr* effect. In this case, these forces also attack the blade with an angle of 45°, which means they may become a strong effect too. If we observe with a bit more attention, however, we deduce that, unlike the *drag* effect, *dragr* is not homogeneous along the '*r*' direction, since it strongly depends on the speed of the *air-particles* reaching the blade on the 'other' side. So, this effect is small for small values of '*r*', but increases fast with the increase of '*r*', since that speed is precisely given by the product $\omega\, r$. On the other hand, anti-torque also increases with '*r*', so, the resultant resistive forces will exhibit a sort of r^2 dependency. The larger the turbine the harder it is to rotate it. The faster it runs, the harder it is to raise its angular speed.

The simplest way of minimising these resistive effects is to impose an appropriate geometry to the blade. In reality, everything comes from geometry, even properties like the resistance of materials, the efficiency of military operations, the transparency of water, etc., everything is intrinsically related to geometry, as we know. Geometry may also induce emergence of properties in complex systems, which is why people form teams or clubs, or birds fly in certain formations, for example. In this case, the blade has to be changed in order to capture the most possible energy coming from the wind, while becoming also as 'transparent' as possible for movements in the '*w*' direction. This is achieved, of course, by twisting the blade for increasing '*r*', in order for it to have a $\theta = 90^\circ$ of attack at its tip. This naturally leads to what we call a '*convergent*' design (see previous articles). One may also find interesting that the turbines used in airplane reactors approach this design. We would therefore expect the ideal turbine, or *superturbine,* to have a large number of blades of this type (to capture a lot of energy) as long as each blade is twisted and made very thin, for helping to minimise the *dragr* effect. The larger the turbine, the thinner the blades should be (low *d*, in the next figure) and the higher the number of blades.

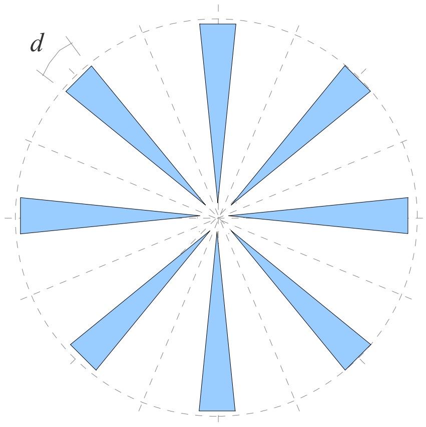


Fig. 3 Convergent design as an optimised solution.

If we observe carefully, also the blades of the huge modern turbines, installed everywhere, get thinner as they go apart from the centre of the machine. That is obviously a strategy aimed at reducing the effect of dragr.

4. **A design from another world**

As we previously said, twisting the blades and making them thinner as they get apart from the central axis of rotation is a strategy for strongly reducing the anti-torque forces produced by the dragr effect. This, however, also reduces the overall torque induced in the machine, since the blades loose their ability to capture the wind energy in the periphery of the machine's circle. So, a natural question will be "is there any other way of reducing dragr?"

The answer is positive, as long as we forget the idea of constraining the blade design to a radial symmetry. There is, in fact, a big problem in radial symmetry: the blade is forced to move in a direction parallel to its driving force (drag + lift), which is a situation that obviously creates a strong effect of dragr, since the area of the blade receiving the reaction of the air when rotating has the same value of that receiving the energy from the wind. The optimum situation would be a large area receiving the energy from the wind and a very small area of contact with the air in the direction of rotation. As shown in the next figure, this could be achieved if the driving force would be perpendicular to the rotation of the blade. Notice that the blade lies on the same plane of the area of the turbine.

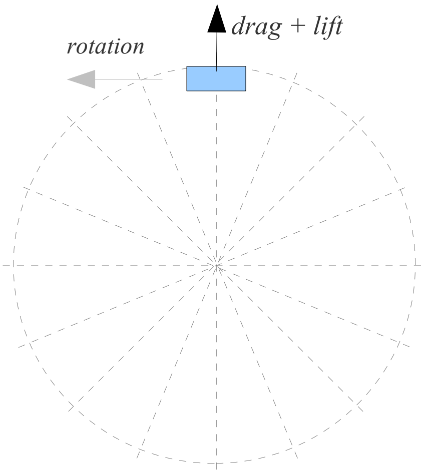


Fig. 4 Non-radial blade, with its driving force perpendicular to the direction of rotation.

Of course the particular situation shown in figure 4 would not easily induce a rotation in the machine, unless the blade would be drawn with a special design in order to create a certain imbalance between the two sides of the system when the wind blows. Anyhow, if we simply translate the rectangular blade to one side of the central axis, as shown in figure 5, we get something really interesting as a result: the machine will rotate to the left due to the torque induced in its axis by the drag+lift force, even if these tend to be perpendicular to the blade's direction of movement. One can imagine, for now, the blade 45° inclinated relative to the wind flow.

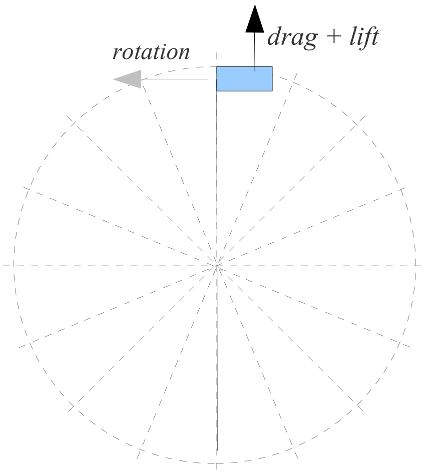


Fig. 5 Non-radial rectangular blade, inducing torque.

And, since this is obviously a case of squaring symmetry, we should add the same effect to each quadrant of the circle, resulting in:

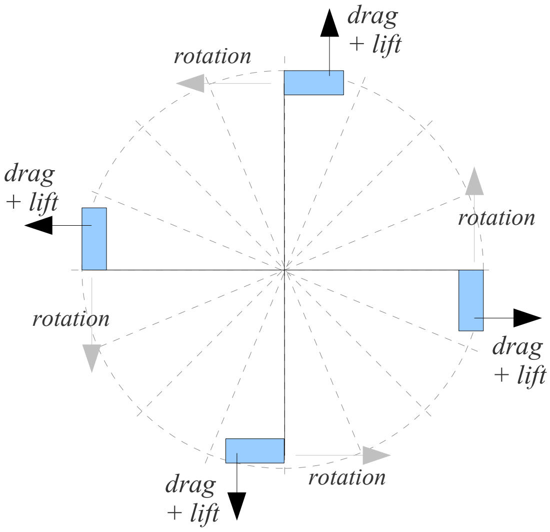


Fig. 6 Rectangular blades mounted in a squaring symmetry.

It now seems obvious that this type of blade will cut very easily through the fluid during rotation.

Obviously, the effect of *dragr* will be almost null at the points of insertion of the blades, even if it slowly increases along the blades' length. This also means that a more general form of turbine can be designed based on such a principle, as shown in figure 7. Notice that all the blades have the same angle of attack in respect to the wind flow, and this angle may even be chosen arbitrarily. A drag machine can be build with this angle being 45°, for example, but a lift machine can also be built, if one chose this angle to be near 20°.

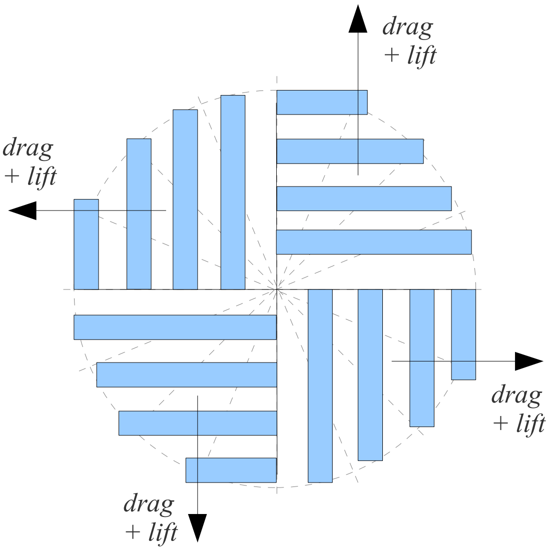


Fig. 7 Rectangular blades mounted in a squaring symmetry.

One may also notice that all the area of the blades contribute to the torque induced in the system, and that this area can easily be changed either by giving the blades a different angle of attack, or changing the blades' thickness, or even using a different number of blades.

In the limit of simplicity, one might consider a turbine with only two sectors, each of which is driven by a single blade, as depicted in figure 8 (2 sectors, order 1). This configuration, however, seems to have no special properties, since it is another way of representing the common drag turbine. But, if we would raise its order, that is, if we use several parallel blades instead of a single one on each side, and those blades become thinner, the overall *dragr* effect would be reduced. Later in this text we will present a model based on this perspective. By using the four quadrants, however, the *dragr* effect will get smaller, and practically null at the four zones of blade insertion. The order 1 of such a model is also shown in figure 8.

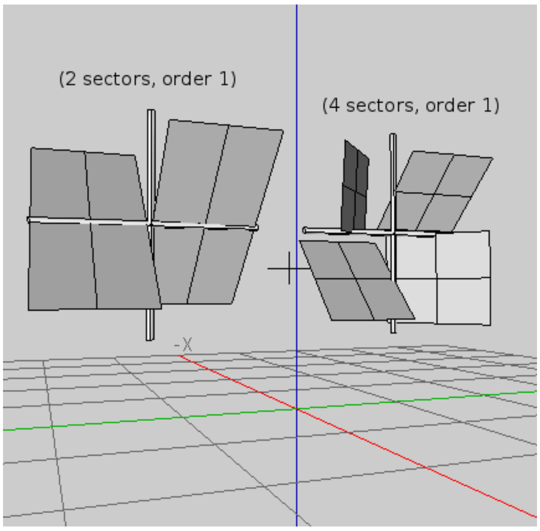


Fig. 8 Hyperturbines of 2 sectors order 1, the minimal construction; and of 4 sectors order 1, with only a blade per quadrant. The wind is supposed to come from our view.

Higher order designs, however, are expected to be more efficient. Depending on the situations in which the system is to be operated, we would expect an order of blades between 5 and 10 to be appropriate, probably. The model shown in the next figure is an example of order 5.

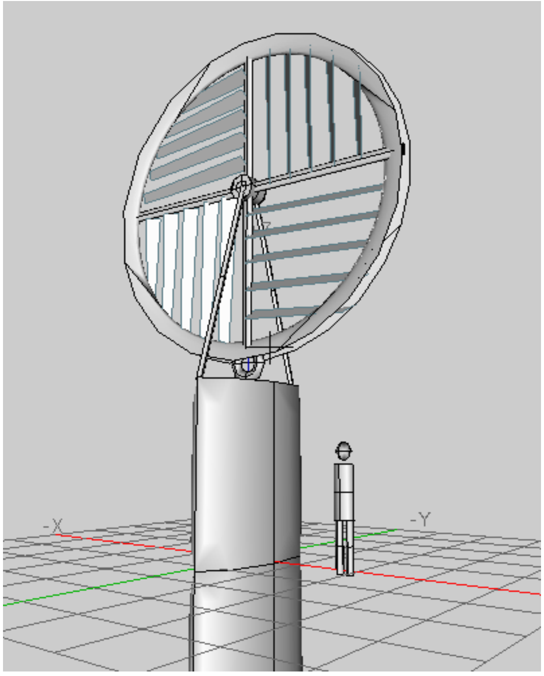


Fig. 9 *Hyperturbine* of 4 sectors order 5, of 1,5KW@10m/s.

By comparing the dimensions of this turbine with the dimensions of the person, we could roughly say it is a machine to be exposed to 7,5KW@10m/s of wind power. If operating with 40% efficiency, that would mean capturing 3,0KW@10m/s. Considering then 50% of efficiency on the injection of this power into the electric grid, by means of the generator and the inverter, we finally may deduce this would be a 1,5KW@10m/s machine, in practice. Its construction can be made very simple and light, which make us believe it may result in a very interesting and powerful machine. Ideally, we envision a transparent one...

The next figure represents precisely the same machine, but now built with a 2 sectors order 11 philosophy. Notice that it will rotate to the right, as the previous one, and this rotation is simply induced by the two sets of 11 blades mounted in inverted angles of attack. A worse performance is expected relative to the previous design, principally due to the less interesting spatial distribution of the *dragr* effect, as we suppose.

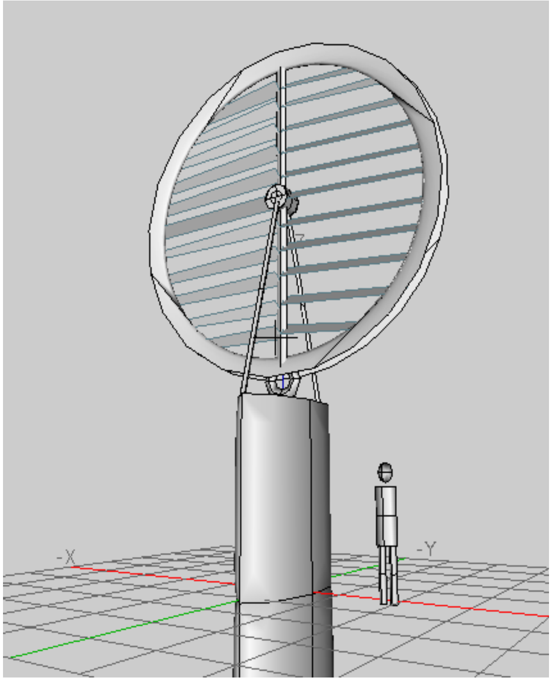


Fig. 10 Same machine, with a 2 sectors order 11 design.

5. **The old design versus the new design**

One thing we consider appropriate now is to try to get an idea about the performances of these new designs by comparing them with the classical radial design. For that purpose, and avoiding once again the usage of complex mathematical models, we will consider the "*technical performance*" of the entire machine as the ratio between the distribution of driving forces and the distribution of resistive forces. Basically, we may define such a ratio as:

$$TechPerform = \frac{(lift + drag)}{dragr} \qquad [1]$$

This is obviously not a precise metric, but it will help us to have an idea about what to expect from the system, as a kind of holistic estimation. Considering what we have said before, we expect a distribution of driving forces similar to the one represented in the next figure, in the case of the radial style used in the '*superturbine*':

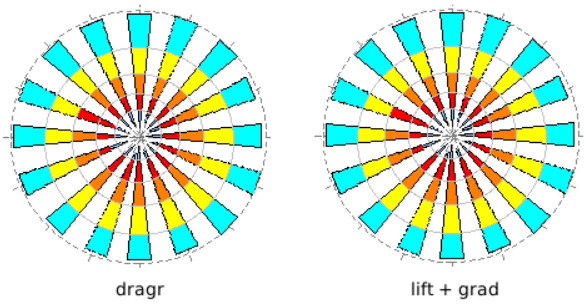


Fig. 11 Purported *dragr* and *lift+drag* effects in the classical '*superturbine*' design. *TechPerfom* approaches 1.

The expected intensity of these effects is shown as a sequence of colours: *red*, *orange*, *yellow* and *blue*; *red* being the most intense. Since the blades of the '*superturbine*' are twisted towards the periphery of the turbine, both effects decrease with increasing '*r*'.

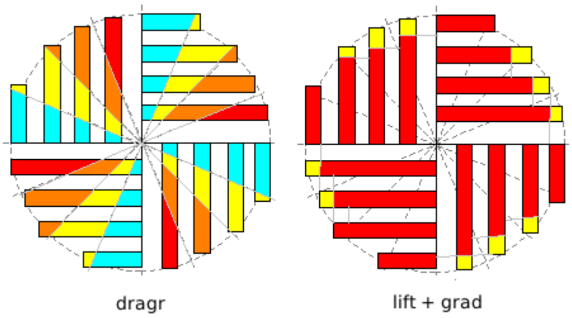
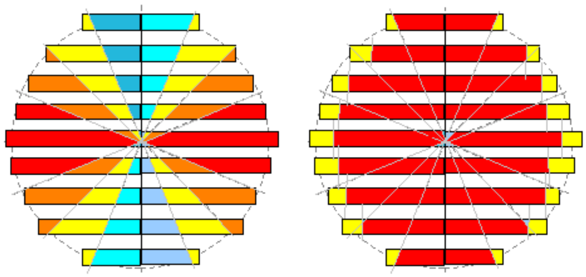


Fig. 12 Purported *dragr* and *lift+drag* effects in an 4 sectors order 4 '*hyperturbine*' design.

In figure 12, however, is shown what we expect to be the distribution of these effects in a 4 sectors order 4 '*hyperturbine*'. This being true, it becomes evident that although the '*superturbine*' design will show a *TechPerform* near 1, this novel type of design will probably exhibit a *TechPerfom* of around 2, considering the amount of the area contributing to each effect. This would mean a turbine performing 2 times better that the previous one.

Finally, let us consider a 2 sectors '*hyperturbine*', as represented in the next figure. By comparing the two areas, it is expectable that the *TechPerform* of this design will also be around 2. We are convinced, however, that it may be slightly less efficient that the 4 sectors case, due to a larger area of concentration of the *dragr* effect.



dragr

lift + grad

Fig. 13 Purported *dragr* and *lift+drag* effects in an 2 sectors order 9 '*hyperturbine*' design.

Notice that in the case of *lift+drag*, the blades were also considered to be slightly twisted near the periphery of the turbine. In practice, this will let us regulate the *tip speed ratio* of the machine.

6. **Why not more than 4 sectors?**

Intuitively, increasing the number of sectors would contribute to a decrease of the *dragr* effects, since the area in contact with the fluid in the '*w*' direction naturally decreases. However, it would also decrease the torque induced by the wind in the machine. Taking into account figure 14, where the cases of 2, 4 and 8 sectors are shown, it will be easy to conclude that the torque induced in the turbine will tend toward null as the number of sectors tend toward infinite.

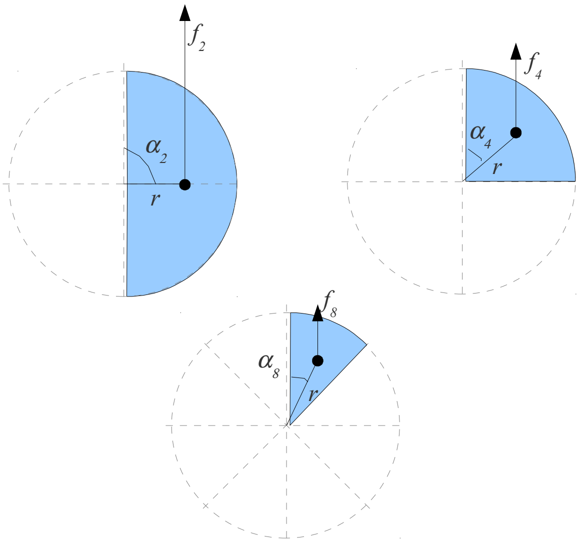


Fig. 14 Comparison between l*ift+drag* forces per sector for the cases of 2, 4 and 8 sectors designs.

Assuming '*r*' practically constant, the effective contribution of these forces to the rotation of the machine is simply their tangential component. Thus, in the first case, the total torque produced in the entire turbine will be given by:

$$T_2 = 2\ r\ f_2\ sin(\alpha_2) \qquad [2]$$

In general, we will have, for *n* sectors:

$$T_n = n\ r\ f_n\ sin(\alpha_n) \qquad [3]$$

But then we may notice that $f_4 = f_2/2$, and $\alpha_4 = \alpha_2/2$. This leading to:

$$T_4\,/\,T_2 = 4\ r\ f_4\ sin(\alpha_4)\ /\ (2\ r\ f_2\ sin(\alpha_2))$$

or

$$T_4\,/\,T_2 = sin(\alpha_2/2)\ /\ sin(\alpha_2) \qquad [4]$$

Since a2 = 90°, this means T4 will be in fact smaller than T2 by the factor *sin(45°)* = 0,71. By applying the same reasoning, we will deduce that, compared with the 2 sectors case, the 8 sectors will be 0,38 times less powerful, the 16 sectors will be 0,20 less powerful, and so on. So, no power will be collected in the limit of an infinite number of sectors. Obviously. It is also true, however, that increasing the number of sectors strongly reduces the *dragr* effects, and this increases the *tip speed ratio*.

7. **The situation of stall**

Strong wind regimens are the most serious challenge for a wind system as a whole. It is simple to design a turbine and its support structure to operate in a low wind speed situation, but it becomes extremely difficult to project it if one considers winds of, say, above 50 Km/h. The power coming from the wind rises with the cube of the fluid speed, so, also it raises with the same ratio the difficulty of maintaining all that structure up and running. Obviously, in a situation of a storm the best thing is simply to get away from the storm: stop the turbine, turn its surface away from the direction of the blow, and, if possible, wait for the 'crises' to pass. The structure of support must, therefore, play a very important role in this process, since it has to be able to handle all the forces generated in such a situation. Engineering is perfectly capable of doing that, but only if we consider stopping the turbine. Otherwise, the very strong torque effects produced in the system due to angular momentum changes would probably become unsupportable. So, it will be a good thing to be sure that the turbine will simply stop rotating in situations of wind speeds superior to, say, 50 Km/h, that is, the turbine stalls. In the '*hyperturbine*' design this can be adjusted by the separation of consecutive blades, as well as by adjusting the width of the blades. The turbine is expected to stall when the force of the wind acting directly in the face of the blade will be of the same amount as the force acting in the opposite face of the blade, which is due both to the *dragr* effect and the part of the flow 'reflected' by the adjacent blade. This means that we can easily adjust the stall of the turbine to fit our purposes.

8. **The importance of gearing**

It is true that when a turbine without load runs fast and easy with the wind it is a symptom of efficiency. It means that the turbine is able to extract the energy coming from the wind and transform it into rotational energy, which is accumulated by the mass of the turbine in the form of angular momentum. Once this energy is transferred to a load, however, the angular momentum decreases, and the turbine would stop if such a transference would be done with 100% efficiency. Fortunately, the maximum transfer of power between the source and the load is known to happen when the load and the internal impedance of the source have the same value. That is, at an efficiency of 50%. Considering the rotational energy in the first situation (no load) given by:

$$E_0 = \tfrac{1}{2} I \, \omega_0^{\,2} \qquad [5]$$

And the rotational energy with load:

$$E_1 = \tfrac{1}{2} I \, \omega_1^{\,2} \qquad [6]$$

Since we have $E_1 = \tfrac{1}{2} E_0$, we may expect a natural reduction in the speed of rotation given by:

$$\omega_1 = (1/\sqrt{2}) \; \omega_0 = 0{,}71 \; \omega_0 \qquad [7]$$

This is a good result, since it means that in fact we do not have to lose a lot of rotational speed when operating with the optimal load. The problem is: due to the inevitable *dragr* effects, most of the wind turbines are not able to rotate at the speeds typically needed by most generators, which are rated at 1000-1500 rpm. In practice, 300 rpm is already very good for a small wind turbine and something that can only happen during generous wind conditions. This, of course, means the generator connected to the turbine should be able to transfer power with a very good efficiency at a rotational speed of 0,7 x 300 = 210 rpm. In practice, this can only be achieved if we use several very strong magnetic poles and lots of copper.

Notice that there are two main ways of achieving good efficiency in a generator (apart from some geometric issues most of the time easily surpassed): 1) increasing the intensity of the magnetic field; 2) increasing the speed of changing of the magnetic field. So, when one is able to induce only a low changing speed in the magnetic field, then one has no other choice but to increase the intensity of the magnetic field. And that means: more magnets, more weight, more space; and the generator suddenly increases in dimensions and costs; it also means a substantial increase in the consumption of natural resources, precious copper, aluminium, iron, etc. So, why not substitute the idea of intensifying the magnetic field with the better idea of changing it faster; with less magnets, less copper, much less weight, higher transportability, etc.

We strongly defend the usage of gearing between the turbine and the generator. Although this is not so easy to implement in the normal *divergent* systems, due to their configuration of blades, both the *superturbine* and the *hyperturbine* designs allow it, since these may be supported by an external circle that can be connected to the generator by means of a secondary circle (Fig. 15). This way, it is very easy to achieve a gear ratio of 10-20x, which is an excellent ratio for the utilisation of inexpensive generators, most of them available in the market. As we can see from the next figure, an option like this may also contribute to the stability of the overall structure of the wind machine, since it represents another point of support for the turbine.

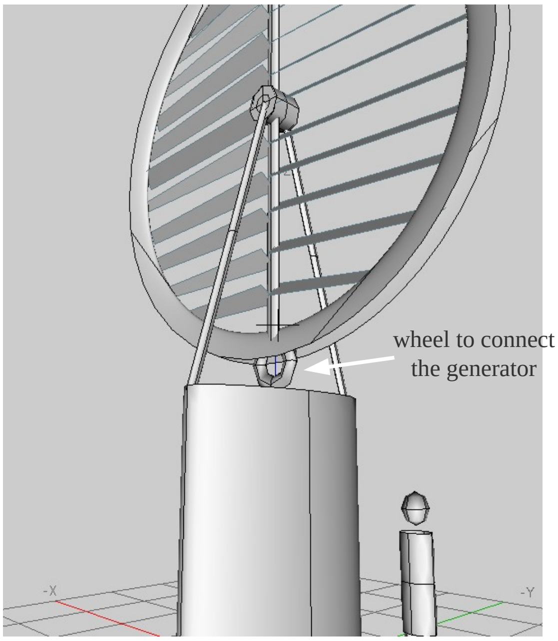


Fig. 15 Secondary wheel, to connect to an inexpensive high speed generator.

This approach has also the advantage of allowing the turbine to rotate slowly, thus implying less *dragr* effects, higher efficiency in capturing energy from the wind, and maximum rotational speeds around 200 rpm. For this to be perfect, the turbine must be well adapted to the characteristics of the generator. Usually, one first thinks on the turbine and then on a generator to fit that turbine design. The problem, in our point of view, must be addressed from the opposite perspective: show me a generator, and I will design a turbine to drive it.

9. Conclusions

The ideas presented in this article represent a novel approach for the design and the construction of wind turbines. From the arguments explicated, we believe this sort of approach will reveal a significant increase in the efficiency of collecting the energy from the wind, compared with the current standards. This impression has been supported by the observation of a scale model of a turbine of 1m diameter running with the wind. The new design also represents a very simple and inexpensive method of construction. Anyone interested in building such a machine will be welcome to contact us. The ideas exposed have to be considered *anti-patent*.

Author's Biography:

J. Manuel Feliz-Teixeira graduated in Physics in the Faculty of Sciences of University of Porto, Portugal, and received an MSc and PhD from the Faculty of Engineering of the same university. His work has been related to various matters, from optical communications, solar energy and seismology, to, more recently, the simulation of complex systems in management science, like warehouse and supply chain. His PhD thesis is on “Flexible Supply Chain Simulation”. Lately he is also dedicated to researching new approaches for renewable energy.