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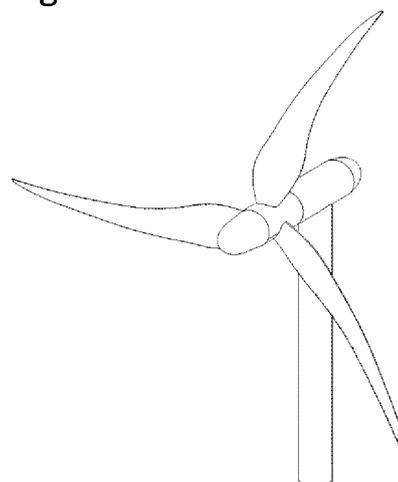
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(54) Title of the Invention: **A tidal turbine blade**
Abstract Title: **Caudal fin shaped blades for horizontal axis turbines**

(57) A caudal fin shaped blade for use on a horizontal axis tidal current turbine is designed by bio-mimicking the Blue Marlin fish caudal fin. A method for forming the blade includes the steps of defining a traditional horizontal axis tidal turbine using a symmetrical airfoil comprising nine airfoil stations placed at 10 percent of the blade, determining a twist angle distribution by creating a twist angle distribution rule for root airfoil and tip airfoil and using a third order polynomial function passing through the centre of each airfoil to twist the blade from root airfoil to tip airfoil.

Figure 1



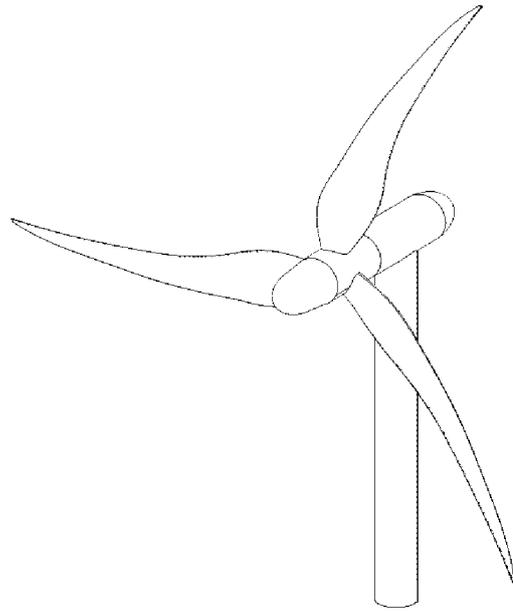


Figure 1



Figure 2

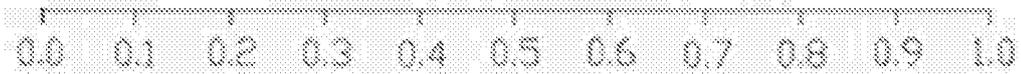
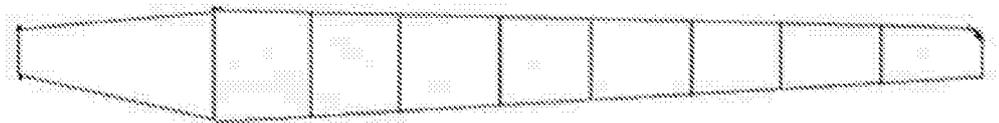


Figure 3

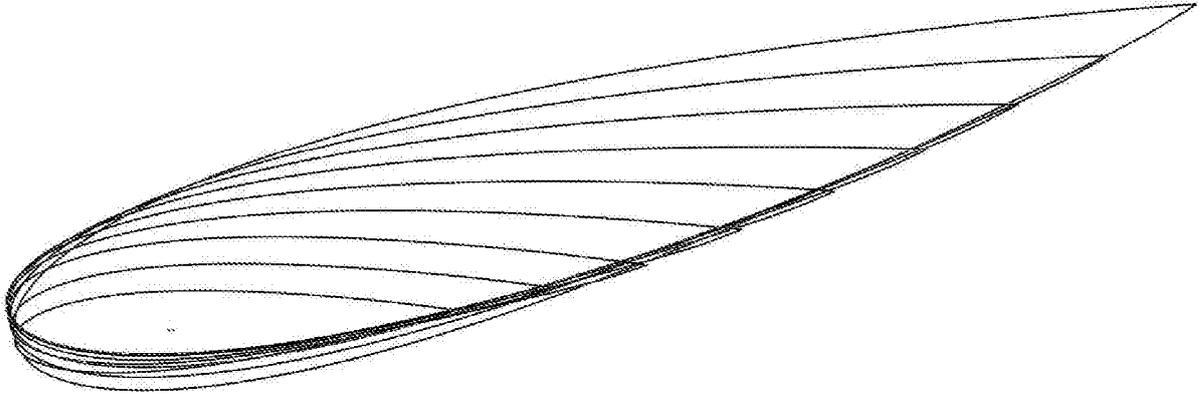


Figure 4

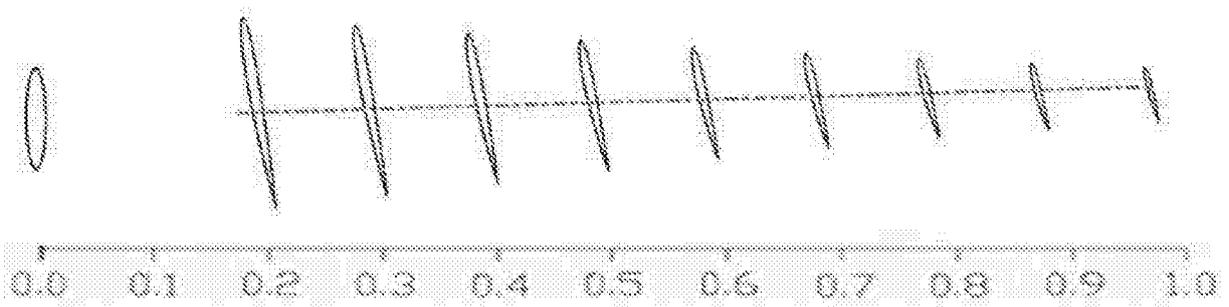


Figure 5

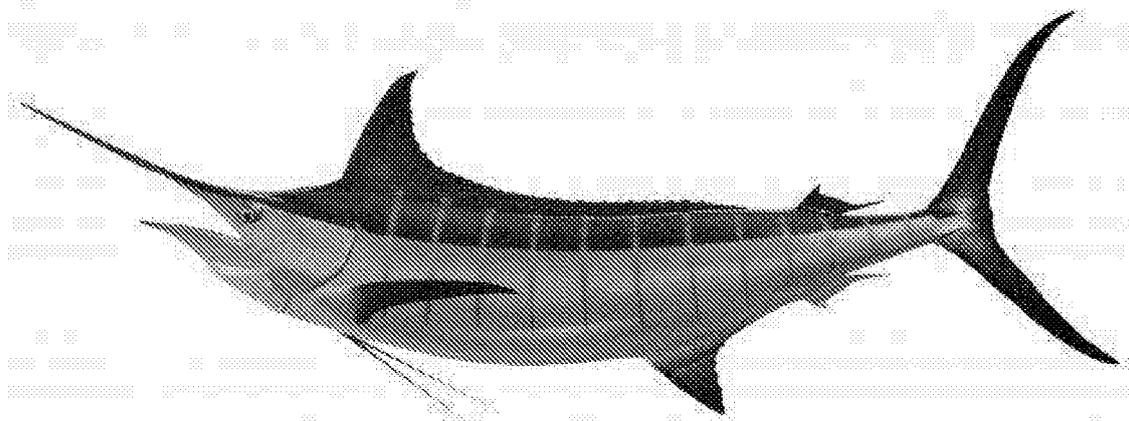


Figure 6

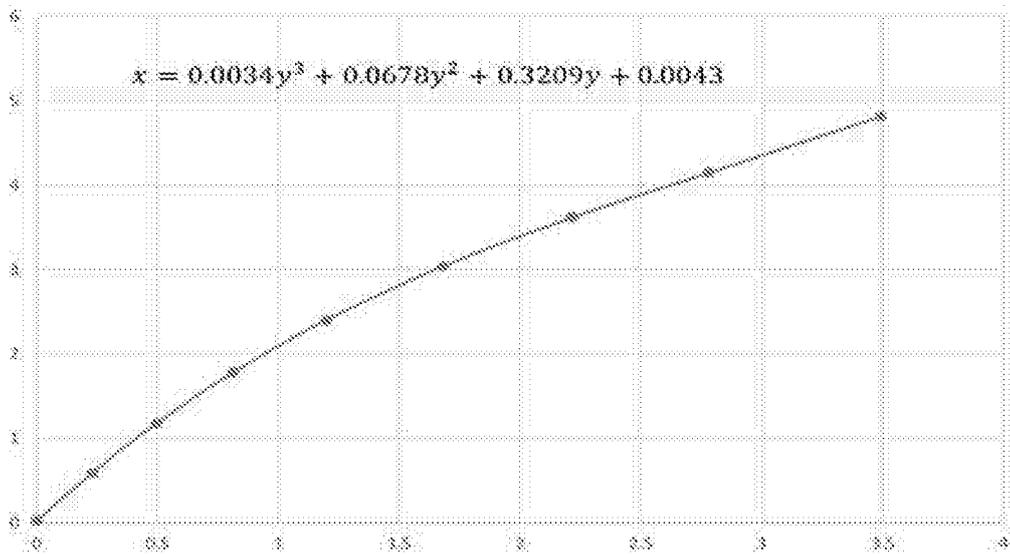


Figure 7

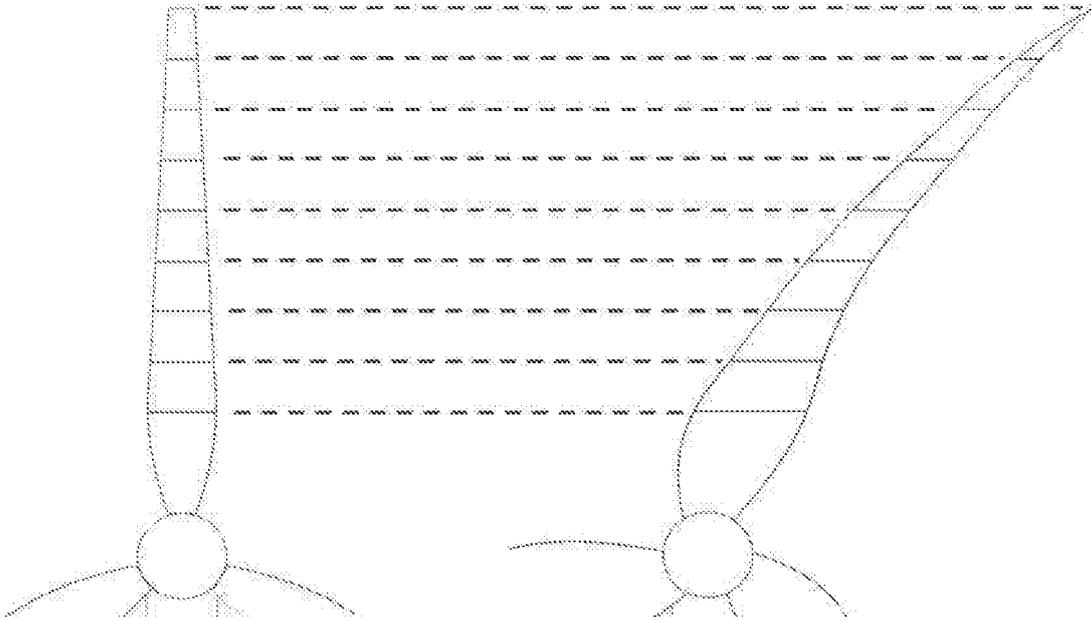


Figure 8

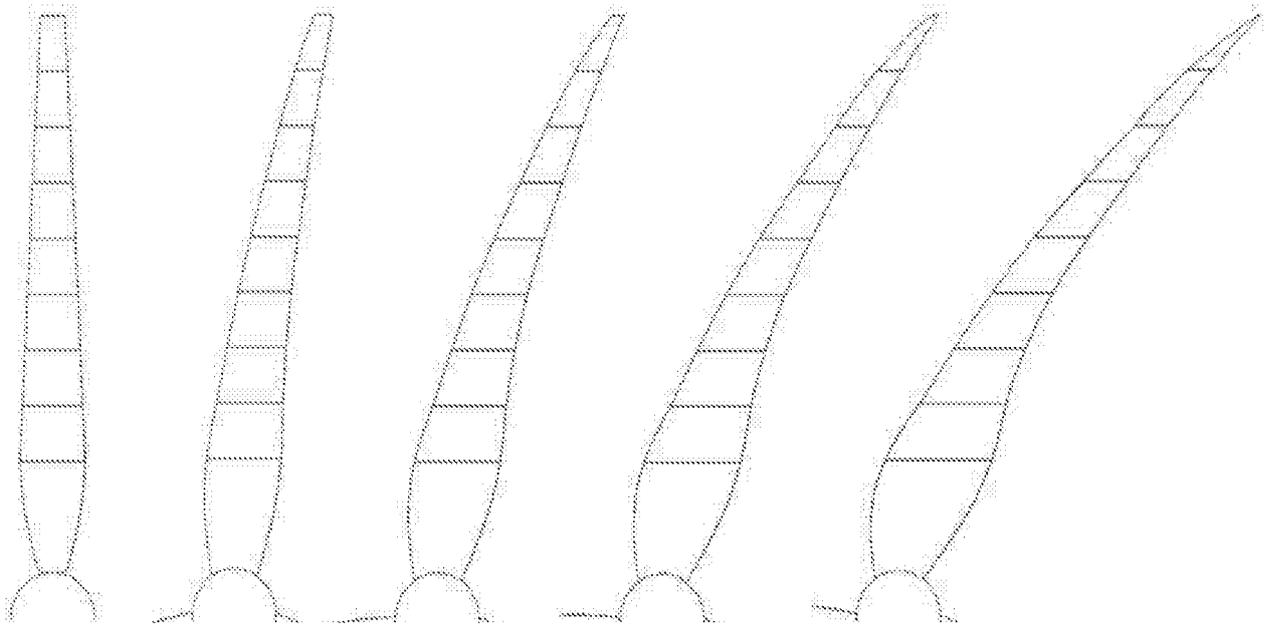


Figure 9

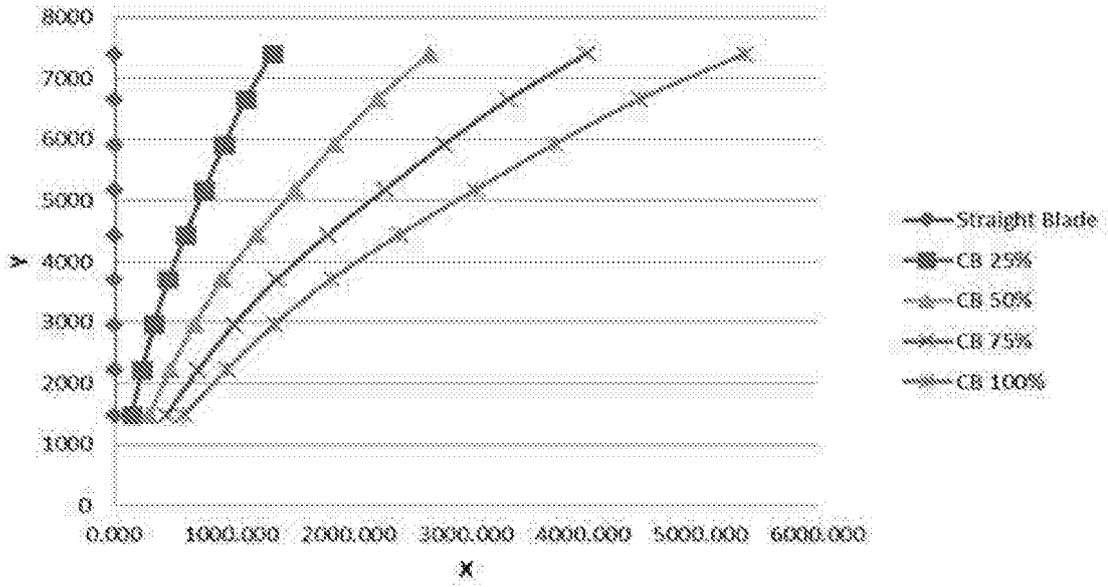


Figure 10

A TIDAL TURBINE BLADE

FIELD OF THE INVENTION

The present invention in general relates to the horizontal axis tidal turbine blades, and in particular to bio-mimicking the Blue Marlin Fish caudal fin to design a HATT in which the curved blade is twisted from the root airfoil station to the tip airfoil station using a novel third order polynomial function to replicate the caudal fin shape of one of the fastest travelling fish in the ocean.

BACKGROUND OF THE INVENTION

Currently, the global energy requirements are met by consumption of the fossil fuels. As the heavy dependence on fossil fuel increases it is becoming a major concern and countries worldwide have now realised the need to incorporate renewable energy sources in their energy policies as an alternative to the fossil fuels (Shields *et al.* 2009). Fossil fuels are very limited with their potential and with the current percentage of fuel consumption, these resources would deplete in coming decades. Thus realising the change in energy policy, renewable energy technologies have become favourable alternative to traditional energy sources. Tidal energy is a renewable electricity source based on the conversion of kinetic energy of moving water into mechanical power. It has fewer CO₂ emissions; it has minimal reliance on fossil fuels (Bryden *et al.* 2007). Solar power, tidal energy, geothermal energy, and wind power are the primary sources of sustainable energy (Yuksel, 2008). Tidal energy has advantages over wind energy, mainly because it is predictable and due to sea water being denser than wind, the available energy can be up to 835 times greater than wind power (Bryden and Couch, 2006).

As a result of this growing interest in the tidal energy, many new tidal turbine blade designs have been created to harness electricity from tidal currents. Tidal turbines are generally classified into two type's horizontal axis tidal turbines ("HATT's"), and vertical axis tidal turbines (VATT's). Both HATT's and VATT's are capable of generating power through the rotation of the turbine blades. HATT's are also called as axial flow tidal turbines, as they have rotational

axis parallel to the tidal current flow; which makes them operate in one direction only. They can be designed using both symmetrical and asymmetrical airfoils; the blades are generally fitted to the hub, to kinetic energy from the water to mechanical energy, and shaft to produce power and gearbox. A traditional HATT has a larger root airfoil chord length and it starts tapering towards its tip airfoil chord length, it also has a twist angle along its entire span to keep the relative angle of attack constant (Myceket *al.* 2013).

On the other hand, bio-mimicry or bio-mimetics has proved to be an excellent motivation to solve complex human problems, by imitating the nature. The design process starts by looking at nature's ecosystem, self-healing abilities or a particular organism, to produce a design solution of the human need. The classic example of the bio-mimicry is the Humpback Whale wind turbine blade of designing an efficient wind turbine blade adapting Humpback whale's flippers and tubercles (Fish & Battle, 1995; Fish *et al.*, 2011). As 80% of the propulsive efficiency i.e. the swimming speed of the Blue Marlin fish is caused due to its high lift generating caudal fin, which makes it one of the fastest propelling fishes under ocean, and also enables it to be efficient even at the low velocities). Thus, a tidal turbine blade design which replicates the caudal fin would produce an optimal HATT producing higher efficiency throughout the year i.e. even for the lower tidal flow velocities. Finally, the overall power coefficient of the designed curved blade would be higher throughout the season.

BRIEF DESCRIPTION OF THE INVENTION

According to the main aspect of an embodiment, this invention provides a bio-mimicked caudal fin shape curved blade, for the use on horizontal tidal turbines to provide optimal efficiency throughout the year than the traditional symmetrical and asymmetrical tidal turbine blades. The blade comprises of a twisted bend from the root airfoil to the tip airfoil stations. The caudal fin shaped blade has a thinner tip than most of the traditional tidal turbine blades, which makes it rotate faster even at low tidal flow velocities, making it optimal annual power producing HATT.

According to the first aspect of the invention, a traditional tidal turbine blade (which is called Straight Blade or SB in this invention) is designed using a “symmetrical” airfoil, comprising of 9 airfoil stations placed at ten percent of designed default HATT. The SB has been using a twist rule with maximum twist angle defined on the root airfoil, and minimum twist angle defined on the tip airfoil. As the rotational velocity of the blade is highest at its tip, the twist angle defined on the tip is at least four times smaller than the root airfoil twist angle. The bend on the caudal fin blade shape is achieved using a novel third order polynomial function passing through the centre of each airfoil, and airfoil stations are stacked long the blade centreline third order polynomial function to resemble the caudal fin shape. A further 3 sets of caudal fin shaped blades were generated in percentage wise chord lengths to demonstrated the strategy to move the straight blade towards the caudal fin shaped blade.

The above mentioned features and aspects of the present invention will be made clear with the references in the following description, and affixed claims. The added drawings, which are integrated in and aggregated in the parts of the specified blade assembly. The advantages, the third order polynomial equation, the strategy to move the caudal fin shaped blade backwards to the straight blade, are illustrated in the embodiments of this invention, and the composition with the explanation, deliver the fundamentals of this invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an isometric view of the bio-mimicked caudal fin blade system.

Figure 2 is a schematic of a symmetrical airfoil which is used as a default airfoil on a horizontal path which rotates around the hub axially (PRIOR ART).

Figure 3 is a perspective view of the symmetrical airfoil distribution in ten percent of the blade radius of the straight blade with the hub distance of the present disclosure.

Figure 4 is a top plan view of the twist angle distribution on the straight blade in the present invention.

Figure 5 is the perspective view of the centreline passing through the individual airfoil station of the straight blade of the present disclosure.

Figure 6 is the schematic of the Blue Marlin fish along with its propulsion attributes (PRIOR ART).

Figure 7 is the skeleton (centreline) of the caudal fin shaped blade fitted with third order polynomial function in the present invention.

Figure 8 is the transitional views of the straight blade to caudal fin shape tidal turbine blade of the present disclosure.

Figure 9 is a schematic of the percentage wise chord length blade progression to the caudal fin shaped blade of the present disclosure.

Figure 10 the skeleton of the strategy to move caudal fin shaped blade backwards (spinal axis variation) to the straight blade in this present invention.

DETAILED DESCRIPTION OF THE INVENTION

References now will be made to the designed caudal fin shaped blade in detail to embodiments of the invention, which includes all the examples of which are demonstrated in the drawings. The caudal fin shaped blade twisted from the root airfoil to the tip airfoil of which the explanation in this invention is provided and not the limitations of this invention. The features described as total blade radius, blade radius, twist angle distribution, airfoil stations would be intended to describe the modifications and variations made through this invention can be used for one embodiment with another embodiment. Thus it is aimed that present invention covers within the scope of the affixed claims, and their proportionate.

Figure 1 shows the isometric view of the designed caudal fin shaped turbine blade inspired by bio-mimicking the Blue Marlin fish caudal fin.

Referring to Figure 2 (after Mohamed, 2012), according to a first aspect of the invention, a “symmetrical” airfoil was used to design the straight blade in this invention. Generally in tidal energy industry, a symmetrical airfoil is used to

design both HATT's and VATT's (Etemadi *et al.* 2011; Rossetti & Pavesi, 2013), due to the angle of attack variation over the full turbine blade rotation and the mainly because of the high cavitation properties (Liu & Veitch, 2011). The word "symmetrical" means that the mean camber of the airfoil is straight and is same as the chord length of the airfoil. Previous examples of the use of symmetrical airfoils in tidal turbine blade design can be found in Masters *et al.* (2013), Yang & Shu (2012), and are also well known to the skilful people in this art. The airfoils travel in a tangential direction in axial path to the tidal current flow, and hence the airfoil chord length is not parallel to the flow like VATT's, but travelling across it. As the fluid velocity increases over the airfoils, the 'convex surface' results in lower pressure on the 'suction' side when compared to the 'pressure side' of airfoil. Therefore using symmetrical airfoils to model a bio-mimicked HATT blade has not been performed to harness energy from the tidal currents. The use of "non-symmetrical" airfoils to design the HATT's are also known. For example, Bai *et al.* (2014), and Wu *et al.* (2013) designed tidal turbine blades using non-symmetrical airfoils which have descending convex bend in the middle of leading edge and the camber inverting point towards the trailing edge. These airfoils are generally designed to have huge unfavourable torque values which also produce lower lift coefficient at the same time. As the tidal current flow increases around the cylindrical leading edge, it results in pressure drop and gives negative pressure inclination. For the given airfoil design, if the water velocity, the angle of attack are higher on the upper surface of the airfoil, it results in higher "drag" force when a HATT completes a full rotation and also causes "lift" fluctuations. The benefit of designing blade like a Blue Marlin caudal fin would generate higher lift and power coefficients at lower and higher tidal current velocities with less vibrations and would be easy to manufacture.

What is needed, therefore is a HATT blade system designed using a symmetrical airfoil, which would produce more lift coefficient, and annual power output throughout the season i.e. for lower and higher tidal current velocities, and can be easily manufactured as well.

Referring now to Figure 3, shown is the symmetrical airfoil distribution along the entire span of the straight blade. The top level design parameters that define the three dimensional straight blade are blade radius, total blade radius, symmetrical airfoils, and twist angle distribution. The span wise distribution of the airfoils is done at every 10% of the blade. The distance between hub circle and the root airfoil is 20% of the total blade radius (R). The diameter of the hub circle is 40% of the root airfoil chord length. For e.g. if the root airfoil chord length is 1000mm then the hub circle diameter would be 400mm (the hub circle is a cylindrical surface which is to be lofted with the root airfoil). After defining the default value of the root airfoil chord length (1000mm), the remaining airfoil chord length distribution is done using a constant reduction factor of 0.08R, which is named as Blade chord length reduction factor and is used to calculate the chord lengths of remaining airfoils. For example, if the root airfoil chord length is 1000mm, For station 1 the airfoil chord length will be 920mm (1000 – 80), similarly for station 3 the airfoil chord length will be 840mm (940 – 80) and so on until the tip airfoil chord length is calculated. The rotor diameter is also a design variable which is retrieved at the theoretical design phase of the tidal turbines parallel with number of blades, hub and nose height, diameter. After determining the above mentioned parameters the rotor span can be fixed. Later on, the airfoil, chord length, and the twist angle distribution are determined.

As shown in Figure 4, a top plan view of the twist angle defined on all the airfoil stations. The blade twist angle is higher at the root airfoil because it experiences less rotational forces on the blade and it gradually starts decreasing towards the entire span of the blade. As the angular velocity of the blade is highest on the tip of the blade the blade twist angle is at least four times smaller than the root airfoil twist angle. Thus a twist distribution rule can be created for example:

NACA-AIRFOIL-ROOT-TWIST-ANGLE = 16° (default)

NACA-AIRFOIL-TIP-TWIST-ANGLE = 4° (default)

BLADE-TWIST-ANGLE-DECREMENT = 4 times

This is a default value which starts from the Root airfoil twist and ends on the tip airfoil, for e.g. if root airfoil twist value is chosen 15° then the tip twist angle will be five times smaller which would then give 3° as the value for tip twist angle. **(NOTE: The centre axis goes with the airfoils).** As the tidal current flow velocity progresses towards the turbine blade, the blade pressure side pressure increases especially at the tip of the blade as it is being affected by the rotational velocity being the highest on the tip of the blade. At the same time having lower blade twist angle at the tip airfoil station would result in positive tip blade vortex on the pressure side of the blade which is the expected behaviour in the high turbulence intensity tidal current flow. The blade tips also experience the highest pressure, which also causes the flow separation in the pressure side and the suction side of the blade. Due to the discussed reasons the blade twist is varied across all the airfoil stations and therefore allowing the straight blade and the caudal fin shaped blade to produce the highest efficiency throughout the season.

Figure 5, shows the creation of the straight blade concept along with the centreline passing through it. In order for a tidal turbine rotor to produce enough annual power output, the total blade radius needs to have a maximum value of 11000mm, and minimum value of 1500mm (Kim *et al.*, 2013; Batten *et al.*, 2008; Batten *et al.*, 2006). As, all the stations of the turbine utilise symmetrical airfoils but have different parameters values for each instance. The NACA stations are placed at the 10% value of the blade as visualised in Figure 5, and the distance between hub circle and the root airfoil chord is 1480mm (20% of the total blade distance, to provide structural strength for the blades to survive high rotational velocities). For example, the root airfoil station has an R value of 5920mm (Total blade radius – hub circle root airfoil distance), Station 1 has the R value which is 10% of 5920 (which yields) 5328mm (5920 - 592) and so on until we reach the value of 1410mm for the tip airfoil station. The next step is to use calculate R values from the hub circle values and “stack” the airfoils along the blade centreline; so that the each individual airfoil can be added a twist angle. Once the coordinate systems for all the airfoil stations are located, the NACA profiles should be referenced to the

blade centreline. The calculation method for defining the variable twist angle for each an individual airfoil is already explained in the above section.

Shown in Figure 6 is a drawing of a Blue Marlin (after King Sailfish Mounts, 2014) with its propulsion characteristics. The swimming and locomotion characteristics of marine like most other mammals differ in size, weight, shape, nonetheless they all live and survive in the unsteady currents in the ocean. Thus certain marine vertebrates function accurately in unsteady and fast seawater currents, the Blue Marlin fish, *Makaira nigricans* swimming speed has been recorded up to 80 km/h (50 MPH), thus these marine vertebrates employ the thrust manoeuvring or in other words they use their ‘fins’ for the propulsion (Lenarz & Nakamura, 1972). The locomotion of the marine vertebrate Blue marlin fish is generally based on the five fins namely; caudal, anal, pelvic, pectoral, and dorsal fins which are located around its body, and the movements caused because of these flexible fins act as the main source for propulsion at high swimming efficiency. The pectoral and pelvic fins contribute to the manoeuvrability to swim at low velocity marine currents, with ‘the caudal fin’ actually causing the essential thrust for propulsion (Tokic & Yue, 2012). The caudal fin propulsion may represent a ship is rudder at high speed or an airplane movement operating with the same forces like pitch and thrust, including the transfer mechanisms like drag and lift. The pressure related forces drag and lift originate due to the inequality of the water flow acting on the fish body. This propulsion is also termed as the Body and/or Caudal Fin (BCF) propulsion (Wilga & Lauder, 2001), which may cause surface area increment or decrement; thus, the swimming movements may differ from species to fish species. Dorsal fins are the easiest to locate in marine vertebrates as they are found in the dorsal part of the spinal cord in fish. The dorsal fins protect the fish from rolling, and help in turning, thus controlling the body at low speeds or to a complete stop (Jayne *et al.*, 1996). The anal fins are located ventrally in the anus region of the fish, and help managing the body orientation to maintain the stability when the swimming velocity increases (Zhou *et al.*, 2008). The caudal fin, which is also termed the tail fin, is located at the end of the fish’s body (caudal peneckle), and is the main fin that produces thrust

propulsion through seawater (Windsor *et al.*, 2010). The propulsive efficiency of the Blue Marlin ranges in between “0.85 to 0.91%” (Barbara *et al.*, 1992; Watanabe & Sato, 2008; Luthy, 2004).

Referring to Figure 7, In order to get the desired curve for the initial tidal turbine blade to move towards the Marlin look alike curved blade (the target shape), a third order polynomial function is defined on the central axis curve which is:

$$x = 0.0034y^3 + 0.0678y^2 + 0.3209y + 0.0043 \quad \text{Eqn. 1}$$

The above equation is considered to be the centreline polynomial function of the curved blade caudal fin (tail). Each NACA profile centre is built about the centreline, the centreline then acts as master and each profile datum sit along its length divided by the height and the numbers of stations stay constant as the default straight blade. Using this approach it would be easy to model the curved shape blade and reduce the computational overhead. All the NACA profile sections are considered parallel to the x-axis i.e. the normal of each NACA section should be y-axis. The skeleton which is fitted on the midpoint of the each airfoil has a decrease in the chord length in the blade span wise direction which increases the surface area of the caudal fin shaped blade. According to a further aspect of the invention, fitting the third order polynomial on the skeleton of the caudal fin look alike centreline, starting at the root airfoil centre and passing through all the airfoil stations till the tip airfoil centre entails the blade bending and thus creation of the caudal fin shaped blade. The straight blade comprising of the symmetrical airfoil stations which have straight mean camber and using the Cartesian coordinates such that of the leading edge of the symmetrical airfoil in a twisted span wise direction makes it possible to achieve the desired caudal fin shaped blade, which can also be called as span wise curvature.

As shown in the Figure 8, the chord lengths of the straight blade can be varied in linear or non-linear progression along the span wise direction to achieve the caudal fin shaped blade. The caudal fin shaped blade also has a thicker base than

the straight blade to mount the caudal fin shaped blade on the rotor without having to use additional support. The blade twist is also varied along all the airfoil stations making the caudal fin shaped blade to produce more energy from the tidal currents. The twist angle mounted on the airfoil stations for the caudal fin shaped blade can be lower than the region of what is mounted on the traditional tidal turbine blades, for the caudal fin shaped blade to be useful and producing optimal in certain low tidal current velocities. This is particularly suitable for the caudal fin shaped blade because of the increasing concave bend and is thinner at the tip and thus should be dimensioned to have sufficient strength at the tip of the blade. The most important design variables that affect the overall efficiency of the horizontal axis tidal turbine system are chord lengths of airfoils, twist distribution, overall span of the blade, angle of attack, angular velocity of the blade, blade material, and the fluid velocity acting on the blade (Afgan *et al.*, 2013; Clancy, 1978; Pinonet *et al.*, 2012; Betz, 1966, Jo *et al.*, 2014). The design variables selected to move the straight blade towards the caudal fin shaped blade are airfoil chord lengths, the total blade span, and twist angle distribution; however the other important design variables that construct a HATT are outside of the scope of this invention.

Referring to Figure 9, the percentage wise chord length computed bisectonal blade progression is demonstrated by mathematically determining a linear progression function to calculate the percentage wise chord lengths. As shown in Figure 9, there are five different sets of designed HATT's, the chord lengths of the caudal fin shaped blades are bigger than the initial straight blade. This embodiment also differs from the initial straight blade as the upper and lower airfoil chord length values are changed radically to replicate the Blue Marlin fish caudal fin using symmetrical airfoil stations. For the default design purposes, the percentage chord lengths were moved in 0%, 25%, 50%, 75%, and 100%". Where 0% would be the initial straight blade chord lengths, and then the chord lengths are increased in 25%, 50%, and 75%, at the same time the total blade radius is kept constant when moving the caudal fin skeleton and the defined third order polynomial function makes sure that the curved geometries always represent a

caudal fin shaped blade. The designer then determines the percentage chord length values using following equation:

$$R_v = \left[\left(\frac{Ed_{val} - St_{val}}{100} \right) (R_p) \right] + St_{val} \quad \text{Eqn. 2}$$

where R_v is the required chord length value, Ed_{val} is the end value of target shape chord length value, St_{val} is the starting chord length value of the initial blade, R_p is the required chord length percentage.

For example The NACA-AIRFOIL-ROOT (Default blade) chord length: $St_{val} = 1000\text{mm}$, and target shape NACA-AIRFOIL-ROOT chord length: $Ed_{val} = 1645\text{mm}$ and the starting percentage value: $R_p = 25$; then substituting these values in the Equation 2 we get the R_v as 1161.25mm (for the root chord length of 25% curved blade). As, 9 airfoil stations were defined for the default straight blade, initial experimentation will also include 9 airfoil stations for each four percentage stages.

Referring now to Figure 10, caudal fin blade spinal axis skeleton is shown, which is consequently generated by the second embodiment which is particularly suitable for the designer to move the caudal fin shaped blade backwards to the straight blade. As tidal turbine blade power coefficient is very sensitive to the blade twist, chord length distribution and mainly the total blade radius, and optimising each and every design variable would be very time consuming and the computational overhead required when experimenting to check the relationship between the design variables and optimisation is massive. To overcome this problem, perturbation of the default blade design method was used. Using this method a new candidate design was produced using the percentage based chord lengths; by a random deviation of the initial default straight blade rather than generating a random blade from scratch. This method was applicable as the design variables were distributed (i.e. chord, twist angle, and span). Using this method percentage based chord lengths were selected and the third order polynomial

function will stay the same assuming that the span or total blade radius will stay same as the straight blade, and can be defined using following equation:

$$T_{ASTN} = T_{SXC} \times \left(\frac{R_p}{100} \right) \quad \text{Eqn. 3}$$

where T_{ASTN} is the required airfoil station value, T_{SXC} is the target shape X-coordinate value for the particular airfoil station, R_p is the required chord length percentage.

For example the NACA-AIRFOIL-ROOT (target shape) X-coordinate value = 595.568mm, and target shape, and the starting percentage value: $R_p = 25\%$; then substituting these values in Equation 3 we get the T_{ASTN} as 148.92mm (for the root chord length of 25% curved blade).

As shown in the examples above, a caudal fin shaped blade is designed by using a symmetrical airfoil, and by transforming the exiting straight blade by introducing a centreline which passes through all the airfoil centres. By integrating a third order polynomial on the centreline allows the twisting of the blade from root airfoil to the tip airfoil, and it is possible to model the Blue Marlin caudal fin look alike blade; thus allowing a designer using CAD. Bio-mimicking the Blue Marlin caudal fin to design a horizontal axis tidal turbine blade is particularly suitable to produce optimal efficiency for higher and lower velocities i.e. throughout the year. The modelled caudal fin shaped blade are dimensioned to have sufficient strength to withstand incompressible tidal current velocities. The caudal fin shaped also has thicker chord length values at the root airfoil station than compared to the straight blade design, and they gradually decrease in the span wise direction to resemble the Blue Marlin caudal fin.

One of the present invention benefits is that a designer can move the straight blade or any traditional blade to model a caudal fin shaped blade in any percentage wise chord lengths required using the percentage wise chord length formula. It is also possible to find an optimal caudal fin shaped by performing further optimisation studies. A strategy to move the caudal fin shaped blade backwards to the straight

blade also allows a designer to easily orient and model the blade shapes in parallel using the caudal fin spinal axis orientation formula and the strategy. The configuration of the caudal fin shaped blade of the present disclosure follow the same placement of airfoils at ten percent of the blade, and the twist angle is also varied in the span wise direction. It should be understood that, the caudal fin shaped blade tip airfoil station is thinner than the straight blade, and may be remodelled for the manufacturing purposes as there wouldn't be any major energy loss by increasing the chord length values up to 10% thicker. The caudal fin shaped blade described here is suitable for a use on power output of 50 to 1300 kW, and tidal current velocities of 0.5 to 3.5 m/s underwater tidal turbines.

While a particular embodiment or all the illustrations that have been described for the straight blade and the caudal fin shaped blade in detail, it is to be understood and will be appreciated are within the scope of the invention are intended to be included herein. While in the embodiments described above some of the features can be modified, lengthened, replaced, and it will be clear to any person skilled in the art that modifications or adjustments not shown are possible without departing from the spirit of the invention as demonstrated through this invention. The invention is therefore to be considered limited solely by the scope of the appended claims.

What claimed is:

1. A caudal fin shaped blade for the use on horizontal tidal turbine blades by bio-mimicking the Blue Marlin fish caudal fin, said blade comprising:
 - a) determining a straight blade having a symmetrical airfoil by
 - i. selecting a symmetrical airfoil to define root airfoil station and the tip airfoil station;
 - ii. placing the designed airfoil stations in ten percent of the blade;
 - iii. the hub circle diameter is forty percent in diameter of the root airfoil chord length;
 - iv. the distance between the hub circle and the root airfoil is twenty percent of the total blade radius;
 - v. defining the airfoil chord length distribution using a constant reduction factor “0.08R”, and calling it blade chord length reduction factor;
 - b) determining twist angle distribution by
 - i. creating a twist angle distribution rule for root airfoil and tip airfoil;
 - ii. the created twist rule for the straight blade has blade twist angle on the tip airfoil is at least four times smaller than the root airfoil; and
 - c) forming a straight blade tidal turbine system with the above mentioned parameters.
2. The design of a straight bladed tidal turbine as claimed in claim 1 wherein
 - a) a centreline is passed through all the airfoil stations defined starting from the root airfoil to tip airfoil, and stacking the airfoils along the centreline to locate the airfoil station coordinate systems, and later referencing them to the blade centreline.

- b) the step of translating the airfoil station of the symmetrical airfoil comprising the translation of the chord lengths in the blade span wise direction in linear progression, by the same distance placement of the airfoil stations.
3. An approach to move the straight blade towards Blue Marlin caudal fin look alike blade as claimed in claim 1 comprising:

- a) a Blue Marlin caudal fin look alike i.e. caudal fin shaped blade is designed by
- i. defining a third order polynomial function on the central axis curve called as the blade spinal axis and bending the airfoil stations to the caudal fin axis according to the following equation:

$$x = 0.0034y^3 + 0.0678y^2 + 0.3209y + 0.0043$$

- ii. twisting the blade from root airfoil to the tip airfoil using the above equation to design the caudal fin shaped blade, with the symmetrical chord lengths of the caudal fin shaped blade being slightly thicker at the root airfoil and thinnest at the tip.
- iii. developing a caudal fin shaped blade by using horizontally defined airfoil chord lengths, twist angle variation for all the airfoil stations and keeping the total blade radius constant as the straight blade.
- b) forming a caudal fin shaped blade with the determined steps as above.
4. A strategy to create further set of caudal fin look alike HATT's as claimed in claim 3 comprising:
- a) a further set of caudal fin shaped blades are created using the percentage wise chords, and the chord lengths of the caudal fin shaped blades get bigger than the previous percentage wise value, according to the following equation:

$$R_v = \left[\left(\frac{Ed_{val} - St_{val}}{100} \right) (R_p) \right] + St_{val}$$

- b) the blade caudal fin spinal axis enables generation of an approach to move the caudal fin shaped blade back to the straight blade assuming that the blade span will stay constant for both the blades, according to the following equation:

$$T_{ASTN} = T_{SXC} \times \left(\frac{R_P}{100} \right)$$

5. The caudal fin shaped blade according to claim 3, is designed by bio-mimicking the Blue Marlin fish caudal fin, and the root airfoil chord length value is slightly bigger than the straight blade designed.
6. The caudal fin shaped blade according to claim 3, where in the total blade radius has a similar value to the straight blade.
7. The caudal fin shaped blade according to claim 3, is twisted from the root airfoil to the tip airfoil to resemble the Blue Marlin fin caudal fin.
8. The caudal fin shaped blade according to claim 1, wherein the hub circle distance is also in forty percent diameter of the root airfoil chord length of the caudal fin shaped blade.
9. The straight blade according to claim 1, wherein the said blade is suitable for use at the twist angles ranging from 16 to 4°.
10. The caudal fin shaped blade according to claim 1, wherein the distance between the hub circle and the root airfoil is twenty percent of the total blade radius of the caudal fin shaped blade.
11. The caudal fin shaped blade according to claim 3, wherein said blade is suitable to have blade span ranging from 1500mm to 11000mm.
12. The caudal fin shaped blade according to claim 3, wherein the root airfoil has the maximum chord length value of the blade span, and gradually decreases towards each of the said tip airfoil being the thinnest to resemble the Blue Marlin fish caudal fin.
13. The caudal fin shaped blade according to claim 3, wherein the defined third order polynomial function on the caudal fin axis will ensure that the said blade will always look alike a caudal fin when varied in percentage wise chord lengths.

- 14.** The caudal fin shaped blade according to claim **4**, wherein the said blade can be designed at any percentage wise chord length value ranging from 0 to 100%.
- 15.** The caudal fin shaped blade according to claim **14**, wherein the said blade will have the same blade span for the designed percentage wise chord length blade value.



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Claims searched: -

Date of search: 6 August 2015

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	-	YouTube, "bioSTREAM Tidal Power System" [online] 15 June 2008. Available from: https://www.youtube.com/watch?v=b09xjnrftQ0
X	-	tidalpower.co.uk, "bioSTREAM" [online] 22 September 2014. Available from: http://tidalpower.co.uk/biopower-systems
X	-	JP H06213136 A (TSUTSUMI) See EPODOC Abstract and figure 1.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

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Worldwide search of patent documents classified in the following areas of the IPC

F03B

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, INTERNET

International Classification:

Subclass	Subgroup	Valid From
F03B	0003/12	01/01/2006
F03B	0013/26	01/01/2006