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(54) Title: WIND TURBINE BLADE WITH DEVICE FOR MODIFYING THE BLADE AERODYNAMIC SURFACE

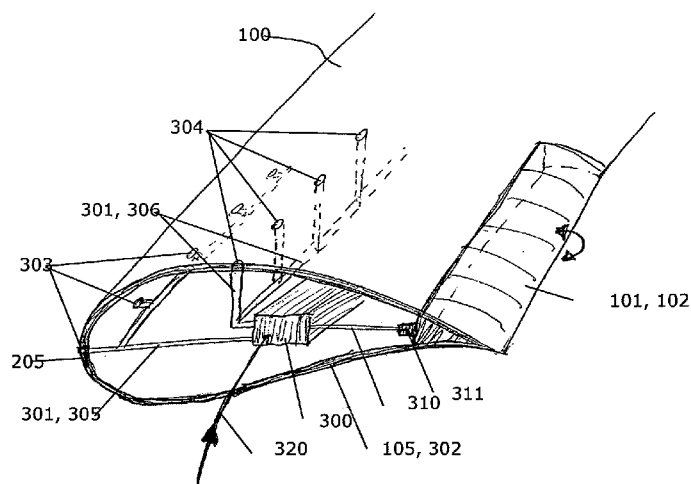


Fig. 3

(57) Abstract: The invention further relates to a wind turbine blade comprising at least one device for modifying the aerodynamic surface or shape of the blade. The device is connected to a drive system for operating the device, and the drive system is arranged such that it is drivable by a pressure difference across the drive system. In one embodiment of the invention the wind turbine blade further comprises a number of conduits guiding a flow of air between an outer surface of the wind turbine blade and the drive system. The invention further relates to a method for operating an aerodynamic device for modifying the aerodynamic surface or shape of a wind turbine blade comprising the steps of exploiting a pressure difference across a drive system, inside or around the wind turbine blade in providing operating power for operating said device.



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WIND TURBINE BLADE WITH DEVICE FOR MODIFYING THE BLADE AERODYNAMIC SURFACE

Field of the invention

5 The present invention relates to a wind turbine blade comprising at least one device for modifying the aerodynamic surface of the blade. The invention furthermore relates to a method for operating one or more of such devices.

Background

10 Most modern wind turbines are controlled and regulated continuously during operation with the purpose of ensuring optimal performance of the wind turbines in all operating conditions, such as at different wind speeds or subject to different demands from the power grid. For instance, at lower wind velocities (typically up to a nominal wind speed of 14 m/s) the turbine is regulated with a view to maximize its power production, whereas the reduction of the loads on the blades, in the bearings, on the tower etc becomes the dominant purpose at higher wind velocities above the nominal wind speed. Desirably, the wind turbine can also be 15 regulated to account for fast local variations in the wind velocity – the so-called wind gusts. Also, as the loads on each of the blades vary due to e.g. the passing of the tower or the actual wind velocity varying with the distance to the ground (the wind profile), the ability to regulate each of the wind turbine blades individually is advantageous enabling the loads to be balanced reducing the yaw and tilt of the rotor.

20 A well-known and effective method of regulating the loads on the rotor is by pitching the blades which can also be performed on the blades individually and cyclically. However, with the increasingly longer blades on modern wind turbines (which of present can be of 60 m or longer) pitching becomes a relatively slow regulation method incapable of changing the blade positions fast enough to account for e.g. wind gusts or other load variations to be compensated for within relatively short periods of time such as within one or half a rotation cycle. 25

Another way of regulating the blades is by changing their aerodynamic surfaces or shapes over parts or the entire length of the blade, thereby increasing or decreasing the blade lift or drag correspondingly. Different means of changing the airfoil shape are known such as different types of movable or adjustable flaps (e.g. trailing edge flaps, leading edge slats or 30 Krueger flaps, Gurney flaps placed on the pressure side near the trailing edge, ailerons, or stall inducing flaps), vortex generators for controlling the boundary layer separation, adaptive elastic members incorporated in the blade surface, means for changing the surface rough-

ness, adjustable openings or apertures, or movable tabs. Such different means are here and in the following referred to in common as aerodynamic devices or devices for modifying the aerodynamic surface or shape of the blade. One important advantage of the relatively small aerodynamic devices is a potentially faster response due to less inertia than if the whole
5 blade is being pitched.

One drawback with the known different systems of various aerodynamic devices of the above mentioned types is however how they are powered. In order to reach the devices potential in the regulation of wind turbines, the aerodynamic surface modifying devices need to be able to operate quickly and repeatedly. Therefore the power consumption could be considerable.

10 In the known systems, the aerodynamic devices are powered directly from the hub via a power link. An electrical cable is however undesirable due to the inevitable implications in relation to lightning. On the other hand air power systems lead to considerable size demands.

Description of the invention

15 It is therefore an object of embodiments of the present invention to overcome or at least reduce some or all of the above described disadvantages of the known systems for control, regulation, and activation of devices for modifying the aerodynamic surface of wind turbine blades.

20 It is a further object of embodiments of the invention to provide a wind turbine blade with regulation means with reduced power consumption. A yet further object of embodiments of the invention is to avoid or at least reduce the need for electrical wiring in the wind turbine blade due to the different regulation means of the blade.

25 In accordance with the invention this is obtained by a wind turbine blade comprising at least one device for modifying the aerodynamic surface or shape of the blade connected to a drive system for operating the device, and the drive system being arranged such that it is drivable by a pressure difference across the drive system.

30 Hereby is obtained a power supply for the operating of any devices capable of modifying the aerodynamic surface of a wind turbine blade which can be driven by energy tapped locally close to the aerodynamic devices to be operated. The drive system capable of using the dynamic pressure energy inside and outside the blade to provide the energy for the actuation of the devices can thus be placed locally optionally further out in the wind turbine blade where the operational power is needed, whereby the need for power links from the hub to the flaps etc is at least partly removed.

Further, the described wind turbine is advantageous in enabling a faster yet robust activation and regulation of the aerodynamic devices in the blade due to their low inertia and the drive system being placed locally near the devices to be operated. A fast regulation system is a prerequisite if the wind turbine blades are to be regulated optimally taking into account fast variations and fluctuations in the wind (e.g. wind gusts or due to tower passage).

In one embodiment, the drive system is placed interiorly in the wind turbine blade adjacent to at least one of the devices.

The wind turbine blade according to the invention may comprise one or more conduits connecting the drive system to an outer surface of the wind turbine blade for guiding a flow of air to or from the drive system. Hereby the local pressure energy around the blade may be guided into and exploited by the drive system. The conduits may advantageously terminate in regions of high or low pressure to provide for maximum power, such as near the leading edge, on the suction side, and/or near the trailing edge of the wind turbine blade. Alternatively, the conduit may terminate at the tip of said wind turbine blade.

In a further embodiment of the invention, the wind turbine blade comprises a conduit connecting said drive system to the root end of said wind turbine blade thereby exploiting the air flow present internally in the wind turbine blade in operation.

The conduits may be at least partly made up by one or more interior surfaces of the wind turbine blade such that the blade shell or beams etc in themselves constitute the conduit.

The internal air flow in the blade can be effectively guided to the drive system by placing the drive system in a partition opening between sections of the wind turbine blade thereby enforcing a greater portion of the air flow to pass the drive system.

In yet a further embodiment of the wind turbine blade, the drive system may comprise a vacuum and/or pressure drive system

In a further embodiment of the invention, the drive system may be connected to a control unit via a signal communication pathway for conveying control signals for said operating of said device. This is advantageous in providing the drive system with information for optimally active regulation and control of the aerodynamic devices during operation, where the devices may be regulated continuously according to the control signals.

In an embodiment of the invention, the communication pathway of the wind turbine blade according to the above comprises a power link. The aerodynamic surface of the wind turbine blade may hereby fast an effectively be regulated and modified continuously according to the signals e.g. from a central control unit placed for instance in the nacelle of the wind turbine. The control signals in the power link are electrical or light or other electromagnetic waves.

The communication pathway in the wind turbine blade according to another embodiment comprises a pressure tube for conveying pressure control signals. Here, the one or more pressure tubes comprise a liquid such as water and/or hydraulic oil, or a gas such as air. By the use of pressure tubes and hydraulics or pneumatics for the control of the valve system, the use of electrical wires in the wind turbine blade can be minimized if not completely avoided.

In a further embodiment, the pressure tube comprises a gas of a lower molecular weight than 28.9 kg/kmol, such as Helium He , Ammonia NH_3 , Hydrogen H_2 , Hydroxyl OH , Methane CH_4 , Natural Gas, Acetylene C_2H_2 , or Neon Ne . Dry air has a molecular weight of 28.96 kg/kmol (as determined e.g. in Chemical Rubber Company, 1983. CRC Handbook of Chemistry and Physics. Weast, Robert C., editor. 63rd edition. CRC Press, Inc. Boca Raton, Florida, USA) depending to some extend on the exact content of the different gasses in the mixture. Because the molecular weight of the gas according to the invention is lower than 28.9 kg/kmol and thereby lower than air, the speed of sound in the gas is correspondingly higher. Hereby is obtained a reduction in the delay of the control signals when sent from the control unit to the valve system as the pressure signals propagate with the speed of sound in the gas. The reduction in the signal delay is correspondingly larger, the longer the distance over which the signals are sent. The reduction of the time needed for transporting the signals is even more advantageous in view of the technological trend to increase the length of wind turbine blades, and as many aerodynamic devices are placed some distance from the blade root where the control signals are likely to terminate. The use of Helium may be further advantageous due to being light in combination with its non-corrosive, non-toxic, and non explosive properties while on the same time being relative easy to acquire.

Further, the wind turbine blade may comprise a feed back system from the device to the drive system for adjusting the operation of the devices according to feed back signals from the feed back system. This further enables an optimal regulation where the required position or operating conditions of the aerodynamic devices can be ensured.

The wind turbine blade according to the former may further comprise one or more actuators connected to the drive system and to the device for operating the device. The actuator can for instance be hydraulic, pneumatic or mechanical.

In a specific embodiment of the invention the device comprises a movable trailing edge. Other possibilities are mentioned in the description.

In yet a further embodiment of the invention the wind turbine blade comprises an accumulator connected to the device. This may be advantageous in working as a back-up system for the drive system, ensuring that a device can be operated at all times independent of the present wind conditions or even during start up of the wind turbine. Such a system may in one embodiment of the invention comprise a pressure tank comprising a gas of a lower molecular weight than 28.9 kg/kmol, such as Helium He , Ammonia NH_3 , Hydrogen H_2 , Hydroxyl OH , Methane CH_4 , Natural Gas, Acetylene C_2H_2 , or Neon Ne .

10 The pressure tank may at least partly be constituted by one or more sections of beam walls of the wind turbine blade.

The invention further relates to a wind turbine comprising at least one wind turbine blade according to any of above mentioned.

15 According to another aspect, the invention relates to a method for operating one or more devices for modifying the aerodynamic surface or shape of a wind turbine blade comprising the steps of exploiting a pressure difference across a drive system, inside or around the wind turbine blade, in providing operating power for operating the device. The advantages hereof are as mentioned previously in relation the different embodiments relating to the wind turbine.

20 Finally, the present invention relates to the use of a pressure difference for providing power to at least partly operate a device for modifying the aerodynamic surface or shape of a wind turbine blade.

Brief description of the drawings

25 In the following different embodiments of the invention will be described with reference to the drawings, wherein:

Fig. 1 shows a sketch of a wind turbine blade according to prior art and comprising movable aerodynamic devices in the shape of a movable trailing edge and vortex generators,

Fig. 2 is a sketch of the pressure distribution around an aerofoil according to prior art,

Figs. 3 shows in a perspective cross sectional view an embodiment of a part of a wind turbine blade according to the present invention,

Fig. 4 is a sketch illustrating the working principle of a wind turbine blade according to an embodiment of the invention exploiting an internal air flow.

5 Fig. 5 shows a sketch of an embodiment of a wind turbine blade according to the invention illustrating the control system of an aerodynamic device in the shape of a movable trailing edge,

Fig. 6 illustrates an embodiment of a wind turbine blade according to the invention where the aerodynamic device is driven by a gas of lower molecular weight than 28.9 kg/kmol and
10 thereby lower than air, and

Fig. 7 shows a sketch of a rotor for a wind turbine, comprising three turbine blades with aerodynamic devices controlled by a control unit and at least partly driven by pressure from pressure tanks in each blade,

15 Detailed description of the drawings

Figure 1 shows a blade 100 for a wind turbine according to prior art and comprising some examples of so-called aerodynamic devices 101. When manipulated, the aerodynamic devices change the aerodynamic surface or shape 105 of the wind turbine blade 100 thereby altering the lift and/or drag coefficients of the wind turbine blade during operation. In the examples
20 illustrated in this figure, the aerodynamic shape 105 of the wind turbine blade 100 can be changed and regulated by changing the position of the movable trailing edge flap 102 placed a distance out along the length of the blade, or by the activation of a number of vortex generators 103 placed closer to the root end 104 of the wind turbine blade on its suction side. As also mentioned in the background description, examples of such aerodynamic devices 101
25 are: different movable or adjustable flaps, e.g. trailing edge flaps 102, leading edge slats or Krueger flaps, Gurney flaps placed on the pressure side near the trailing edge, ailerons, or stall inducing flaps, vortex generators 103 controlling the boundary layer separation, adaptive elastic members incorporated in the blade surface, means for changing the surface roughness, adjustable openings or apertures, or movable tabs.

Traditionally, the various aerodynamic devices 101 are powered directly from the hub via some kind of power link 105 as sketched in figure 1. An electrical cable is however undesirable due to the inevitable implications in relation to lightning. Alternatively, the various aerodynamic devices 101 may be powered directly from the hub by means of air powered links which however lead to considerable size demands for modern wind turbine blades of 60 m or longer.

According to the present invention, such problems are reduced or solved by fully or partly (in time and/or in amount) powering the operation of the aerodynamic devices 101 locally in the blade by tapping dynamic pressure in different ways as will be further explained in the following.

Figure 2 illustrates a typical pressure distribution 200 around and on the surface 105 of an airfoil 201 corresponding to the outer cross sectional geometry of a wind turbine blade 100 at some position down the length of the blade. Typically, during operation a positive pressure 203 is present on the pressure side 204 of the airfoil including at the leading edge 205 whereas a negative pressure 206 is present on the suction side 207 of the airfoil. The pressure distribution depends (apart from the aerodynamic surface geometry) upon the actual angle of attack of the blade and on the velocity of the wind.

As sketched in figure 3, these differences in pressure are exploited to drive and energize a drive system 300 which in turns operate the required devices 101 for altering the aerodynamic surface 105 of the blade 100. Figure 3 shows a part of a wind turbine blade 100 seen in a perspective cross sectional view. Any internal spars or beams or alternative stiffening structure of the blade are not shown for clarity. A number of conduits 301 such as hoses or pipes connect the exterior of the blade to the drive system 300 guiding ambient air as an air flow to and from the drive system due to the pressure differences at the in- and outlets positions 303, 304. In figure 3 one first set of conduits or pipes 305 end on the blade exterior or outer surface 302 near the blade leading edge 205 where a positive pressure is most often present during operation of the wind turbine. Further, a second set of conduits or pipes 306 terminates on the suction side 207 of the blade airfoil where a negative pressure is typically present during operation.

A pressure difference could of course alternatively be realized with conduits ending at other positions on the outer surface of the wind turbine blade with a view to the pressure distribution around the wind turbine blade for different aerodynamic surface geometries, different angles of attack, and different wind velocities. Optionally, the pressure difference across the drive system 300 could also be realized by exploiting the difference in pressure from somewhere on the exterior surface of the blade to a position within the blade. The drive system

could both work as a vacuum system or as a positive pressure system, the latter having the advantage of being able to operate with larger pressure differences whereby the same magnitude of forces can be obtained with a physically smaller system.

5 The drive system 300 yields as output 310 an actuation power to one or more aerodynamic devices 101 for modifying the aerodynamic surface of the wind turbine blade as illustratively exemplified with a movable trailing edge 102 in figure 3. The actuation power could for instance be in the form of a pneumatic, a hydraulic pressure, or a force link directly to the aerodynamic device 101 or indirectly via one or more actuators 311. Different types of actuators could be applied such as for example pneumatic, hydraulic, and/or mechanical actuators.

10 All or some of parts (conduits, inlets, valves, cylinders etc) in the described system for powering and controlling the devices for modifying the aerodynamic profile of the wind turbine blade can advantageously be made of lightweight and electrically non-conductive materials such as for instance plastics. Hereby is obtained both a system of low weight which is advantageous in adding minimally to the undesirable loads in the rotor caused by the weight of the
15 wind turbine blade. Furthermore the use of electrically non-conductive materials is advantageous from lightning considerations. Further some of the parts in the described system according to the invention may be fully or partly embedded in the blade parts during manufacture improving the durability of the system parts under use.

20 In a further embodiment of the invention, the drive system 300 is also connected via a signal communication pathway 320 to a control unit 510 from which control signals 320 comprising information on the desired operational parameters of the devices for modifying the aerodynamic surface. The drive system 300 may be connected to the actuator 311 via a valve system 504 which based on the control signals 320 from the control unit 510 controls the driving force and hereby the position and movement of the aerodynamic device 101.

25 The signal communication pathway 320 conveying or sending the control signals to the drive system and/or the valve system for controlling the actuator(s) may for instance be a power link which is advantageous in being simple and inexpensive to imbed or in other ways establish within the blade body and in providing fast signals over long distances.

30 In another embodiment the signal communication pathway may comprise one or more pressure tubes for conveying pressure control signals,- either pneumatic or hydraulic. In the latter case the hydraulic fluid may be for instance water, or a type of hydraulic oil. If the control signals are pneumatic, the pressure tubes may comprise a gas such as air. Air is advantageous for the obvious reasons of requiring no special safety provisions towards leaks, in-

flammability etc. By sending the control signals 320 without the use of electrical wires and electrically conductive materials,- for instance by the use of pressure signals,- the risk of damages from lightning. is minimized.

5 The signal communication pathway may be connected directly to the control unit or indirectly via a signal interface. The control unit may be placed in the blade body 107 itself for instance in a root portion 104 of the blade or it may be placed in the hub or the nacelle of the wind turbine. The signals sent by the control unit operating the valve system may be based on different system parameters for the wind turbine such as rotational speed, weather conditions (e.g. wind velocities, temperature, humidity), the present and desired power yield,
10 tower or nacelle accelerations etc. The system parameters may be received from e.g. sensors placed on the blades, nacelle or tower, from its surroundings, from other wind turbines in the same wind park, from the power grid etc.

The control unit could be placed outside the wind turbine blade such as in the hub and could optionally be connected to the drive systems in all the blades of the wind turbine. Hereby all
15 or some of the blades could be regulated and controlled together as a whole, for instance simultaneously or suitably delayed taking cyclic effects into account in the regulation. Further, connecting all the wind turbine blades to a common control unit makes it possible to regulate the blades with a view to minimizing the yaw of the rotor.

The drive system could in one embodiment of the invention comprise a servomechanism optionally (but not necessarily) also comprising a feed-back system to the movable or adjustable aerodynamic device. The feed-back system then correlates some actual condition parameter (such as e.g. the position) of the aerodynamic device to the desired condition for the device for instance being pre-defined or being given by some control signal. In another embodiment the feed-back system could correlate the actual condition of the aerodynamic device directly to the pressure difference experienced by the drive system. In this way the system could be designed to keep on adjusting the aerodynamic profile until some given pressure differences were attained and thereby a desired pressure distribution around the airfoil. Hereby in other words obtained a passive and automatic operating and regulation system
25 where the aerodynamic device adapts itself according to the pressure distribution profile
30 around the wind turbine blade.

The servomechanism could for instance be a pressure servo or a vacuum servo similar to the ones applied in many car braking systems.

In a further embodiment of the invention, the wind turbine blade could also comprise an accumulator of some sort acting as a secondary back-up system for the power supply to the aerodynamic device. The accumulator could for instance be a conventional battery or an air accumulator using a pressure chamber for accumulating vacuum or over-pressure. The accumulator could act to supply part of or all of the driving power to the aerodynamic device during some time periods, or could supplement the previously described system in supplying a part of the needed power at all times. The accumulator may be directly connected to the drive system or may be connected directly to the actuator via a valve system as sketched in figure 5.

A section of the spar or beams within the blade shell could advantageously be closed off and used as an air pressure chamber in which either vacuum or an over-pressure is built up continuously by a further set of conduits guiding a pressure difference to the air tank. Alternatively, the pressure chamber may be connected to and pressurized by a pressure setting device such as e.g. a compressor or a pump 503. The pressure setting device 503 may be placed in a root portion 104 of the blade or alternatively in the nacelle or the hub of the wind turbine.

By regulating the pressure from the pressure chamber or reservoir by means of the valve system 504, a faster and a far more precise and accurate control of the driving pressure can be obtained instead of e.g. regulating and adjusting the pressure in the pressure chamber according to the driving pressure needed without a controllable valve system.

Also, compared to the control system according to prior art of figure 1 of air power links directly from the hub to the actuators, the use of the pressure chamber or reservoir ensures a large source of a more constant driving pressure to be present.

Additionally, the wind turbine blade 100 may comprise one or more drainholes 231 for allowing water, small dirt particles etc to escape from the interior of the blade body 107. Such drainholes may advantageously be placed near the tip of the blade and/or near the trailing edge. The wind turbine blade may also comprise a lightning arrestor device 232 for catching lightnings and guiding them safely to the ground without damaging the material or other devices in the blade body 107.

The described drive system could also transform all or parts of the pressure energy into electrical energy used to power for instance a warning light near the tip of the blade. This re-

quires an electrical power link from the drive system which is disadvantageous out of lightning consideration. However, as the drive system according to the invention can be placed quite far out in the blade, the electrical wiring needed to a warning light in the tip of the blade would still be less than if the warning light is powered directly from the hub.

- 5 In another embodiment of the invention the drive system 300 is driven by the air flow 400 from the blade root end 104 towards the blade tip 401 which is naturally present within the wind turbine blade when rotating 402. This is illustrated in figure 4 showing a wind turbine blade 100 with a device for changing the aerodynamic surface of the blade which in the figure is illustrated by a movable trailing edge flap 402. As in the previous embodiments, the aerodynamic device 402 is operated by means of a drive system 300 placed within the wind turbine blade 100. The drive system 300 is powered by the pressure difference across the drive system i.e. the difference in pressure from the root end 104 to some opening 403 in or near the tip 401 of the wind turbine blade resulting in an outward air flow 400. The opening or outlet 403 near the tip 401 could simultaneously also function as a drain hole allowing water and small dirt particles to escape the cavity or cavities of the wind turbine blade. As sketched in figure 4 the drive system could advantageously be placed in an opening in a wall partition 404 between sections of the blade thereby maximizing the extraction of energy from the air flow 400. The drive system 300 could in this embodiment comprise some sort of turbine converting the fluid energy into a mechanical, electrical, pneumatic, hydraulic, and/or electrical output for the operation of the aerodynamic device 101. In the illustrated embodiment in figure, the conduits guiding the air flow to the drive system are constituted in whole by interior wall surfaces 405 of the blade itself. Alternatively, air could be guided to and from the drive system by means of e.g. hoses or flexible tubes. In one embodiment of the invention air could also be guided to the blade root from e.g. the spinner in the nacelle via special air intakes and conduits whereby a flow is avoided or at least minimized within the hub where the pitching systems, electronics, coolers, and other equipment sensitive to dust, humidity etc. are present.

- The operating speed of the aerodynamic devices and therefore of the actuators affects the efficiency of the wind turbine in enabling the wind turbine to be optimally controlled for a longer period of its time in operation. Optimally controlled may in some scenarios depending on the actual wind situation imply to maximize the power output of the wind turbine or in other scenarios to minimize the loads exerted by the wind on the different parts of the wind turbine.

- One parameter influencing the operational speed is the length of the communication pathway between the valve system and the control unit operating the valve system. If air is used as the driving media in the pressure tubes for communicating the signals, the information sig-

nals (being the pressure changes in the tubes) propagate with the speed of sound in the air of approximately 344 m/s at 20°C. For a 33m long distance (corresponding to a typical distance for many proposed blades with trailing edge flaps) this yields a delay of the pressure signal of about 0.1 seconds.

- 5 According to an embodiment of the invention, a gas or a gas mixture of a lower molecular weight than 28.9 kg/kmol and thereby lower than air (having a molecular weight of 28.96 kg/kmol) is used as the driving media in the pressure tube. Such a gas could for instance be Helium (*He*) or Hydrogen (*H₂*). Hereby is obtained an increase in the operational time of the system. The speed of sound in a gas squared is inversely proportional to the molecular
- 10 weight of the gas in question. Thus, the lower the molecular weight of the gas, the higher the speed of sound. Examples of densities and molecular weights of some different gases are shown in the table below also including the data from dry air for comparison. The gasses in the table all have a lower molecular weight than air wherefore the speed of sound and thus the speed of the pressure changes constituting the information signals in the communication
- 15 pathway according to the invention is higher yielding faster operation times of the proposed control system. In the case of Helium, the molecular weight is approximately 4.02 yielding a speed of sound of around 927 m/s at 20°C or almost three times as high as in air. For the same example as above of a 33m long distance this yields a significantly smaller delay of the pressure signal of about 0.03 seconds.
- 20 In other embodiments the pressure tube comprises any of the following gases or mixtures hereof: Helium *He*, Ammonia *NH₃*, Hydrogen *H₂*, Hydroxyl *OH*, Methane *CH₄*, Natural Gas, Acetylene *C₂H₂*, or Neon *Ne*.

Gas	Formula	Molecular weight (kg/kmol)	Density (kg/m ³)
Acetylene (ethyne)	<i>C₂H₂</i>	26.04	1.092 1.170
Air		28.96	1.205 1.293
Ammonia	<i>NH₃</i>	17.031	0.717

			0.769
Helium	<i>He</i>	4.02	0.1664
Hydrogen	<i>H₂</i>	2.016	0.0899
Hydroxyl	<i>OH</i>	17.01	
Methane	<i>CH₄</i>	16.043	0.668 0.717
Natural gas		19.5	0.7 - 0.9
Neon	<i>Ne</i>	20.179	
Water Vapour	<i>H₂O</i>	18.016	0.804

In one embodiment of the invention, air which is cheap and non-complicated to use, is used as the powering medium in the pressure chamber if present, while another medium with a lower molecular weight (as e.g. suggested in the table above) is used for the control signals.

- 5 This other medium may be more expensive but on the other hand only a very limited quantity is needed for the control signals.

In one embodiment of the invention, a gas of lower molecular weight than air as discussed above may also be used as pressure medium in the pressure tank. In a further embodiment as illustrated in figure 6, the devices for controlling the aerodynamic surface or shape of a blade 101 may be controlled by a pneumatic actuator 311 driven by a gas of lower molecular weight than air and at least partly driven directly or indirectly by a pressure setting device 503. The gas is then guided via pressure guiding means such as pressure tubes or hoses 601 (and optionally via a pressure tank 501) to drive the actuator 311. The driving pressure on the actuator 311 is in the embodiment of figure 6 controlled by a control unit 610 acting on the pressure setting device 503. As the case in the previous embodiments, the pressure setting device and/or the control unit may be placed in the blade body 107 itself e.g. in a root portion of the blade, or may be placed outside the blade in the hub or nacelle of the turbine.

In figure 7 is shown an embodiment of the invention of a wind turbine rotor 700 in this case comprising three blades 100. Each blade 100 comprises one or more devices for modifying its aerodynamical surface or shape of the blade 101 which are activated partly or fully by pressure from a pressure tank 501 in this embodiment placed a distance out in the blade. Here, one pressure setting device such as a compressor or a pump 503 keeps the pressure in all three pressure tanks within a desired level via pressure hoses 601 from the compressor or pump to the pressure tank. Similarly only one control unit 510 is in this example coupled via communication pathways 320 to the valve systems (not shown) in all three blades thereby controlling the pressure guided from the pressure tanks to the pneumatic actuators of the aerodynamic devices 101. The communication pathways may be directly connected to the control unit or indirectly via signal interfaces. By letting a central control unit operate all or some of the aerodynamic devices in all the wind turbine blades, the control unit may control and regulate all the blades in unison or alternatively in dependence of each other taking for instance cyclical effects into account such as the tower passage or the wind velocity varying with the distance from the ground.

In one embodiment, sensors signals of e.g. velocities or accelerations measured on one blade may be used in controlling the aerodynamic devices on the following wind turbine blade 120 degrees later in the rotor rotation, the blade in this way being optimally operated according to its present and current conditions as measured by the preceding blade. Further, connecting all the wind turbine blades to a common control unit makes it possible to regulate the blades with a view to minimizing the yaw of the rotor.

While preferred embodiments of the invention have been described, it should be understood that the invention is not so limited and modifications may be made without departing from the invention. The scope of the invention is defined by the appended claims, and all devices that come within the meaning of the claims, either literally or by equivalence, are intended to be embraced therein.

Claims

1. A wind turbine blade comprising at least one device for modifying the aerodynamic surface or shape of the blade connected to a drive system for operating said device, the drive system being arranged such that it is drivable by a pressure difference across the drive system.
- 5 2. A wind turbine blade according to claim 1 where said drive system is placed interiorly in said wind turbine blade adjacent to at least one of said devices.
3. A wind turbine blade according to claim 1 or 2 comprising one or more conduits connecting said drive system to an outer surface of the wind turbine blade for guiding a flow of air to or from said drive system.
- 10 4. A wind turbine blade according to claim 3, where at least one of said conduits terminates near the leading edge, on the suction side, and/or near the trailing edge of said wind turbine blade.
5. A wind turbine blade according to claim 3 or 4, where at least one of said conduits terminates at the tip of said wind turbine blade.
- 15 6. A wind turbine blade according to claim 1 or 2 comprising at least one conduit connecting said drive system to the root end of said wind turbine blade.
7. A wind turbine blade according to claim 6, where said at least one conduit is at least partly made up by one or more interior surfaces of said wind turbine blade.
8. A wind turbine blade according to any of the preceding claims, where said drive system is
20 placed at least partly in an opening in a partition between sections of the wind turbine blade.
9. A wind turbine blade according to any of the preceding claims, said drive system comprising a vacuum and/or pressure drive system.
10. A wind turbine blade according to any of the preceding claims, where said drive system is connected to a control unit via a signal communication pathway for conveying control signals
25 for said operating of said device.
11. A wind turbine blade according to claim 10 where the at least one communication pathway comprises a power link.

12. A wind turbine blade according to claim 10 where the at least one communication pathway comprises a pressure tube for conveying pressure control signals.
13. A wind turbine blade according to claim 12 where said pressure tube comprises a gas such as air.
- 5 14. A wind turbine blade according to claim 12-13 where said pressure tube comprises a gas of a lower molecular weight than 28.9 kg/kmol, such as Helium *He*, Ammonia *NH₃*, Hydrogen *H₂*, Hydroxyl *OH*, Methane *CH₄*, Natural Gas, Acetylene *C₂H₂*, or Neon *Ne*.
15. A wind turbine blade according to claim 12 where said pressure tube comprises a liquid such as water and/or hydraulic oil.
- 10 16. A wind turbine blade according to any of the preceding claims, comprising a feed back system from said device to said drive system for adjusting said operation of said devices according to feed back signals from said feed back system.
17. A wind turbine blade according to any of the preceding claims, comprising one or more actuators connected to said drive system and to said device for operating said device.
- 15 18. A wind turbine blade according to any of the preceding claims, where said device comprises a movable trailing edge.
19. A wind turbine blade according to any of the preceding claims comprising an accumulator connected to said device.
- 20 20. A wind turbine blade according to claim 19 where said accumulator comprises a pressure tank comprising a gas of a lower molecular weight than 28.9 kg/kmol, such as Helium *He*, Ammonia *NH₃*, Hydrogen *H₂*, Hydroxyl *OH*, Methane *CH₄*, Natural Gas, Acetylene *C₂H₂*, or Neon *Ne*.
21. A wind turbine blade according to claims 19-20 comprising a pressure tank at least partly constituted by one or more sections of beam walls of the wind turbine blade.
- 25 22. A wind turbine comprising at least one wind turbine blade according to any of the claims 1-21.

23. A method for operating one or more devices for modifying the aerodynamic surface or shape of a wind turbine blade comprising the steps of exploiting a pressure difference across a drive system inside or around the wind turbine blade in providing operating power for operating said device.

- 5 24. Use of a pressure difference for providing power to at least partly operate a device for modifying the aerodynamic surface or shape of a wind turbine blade.

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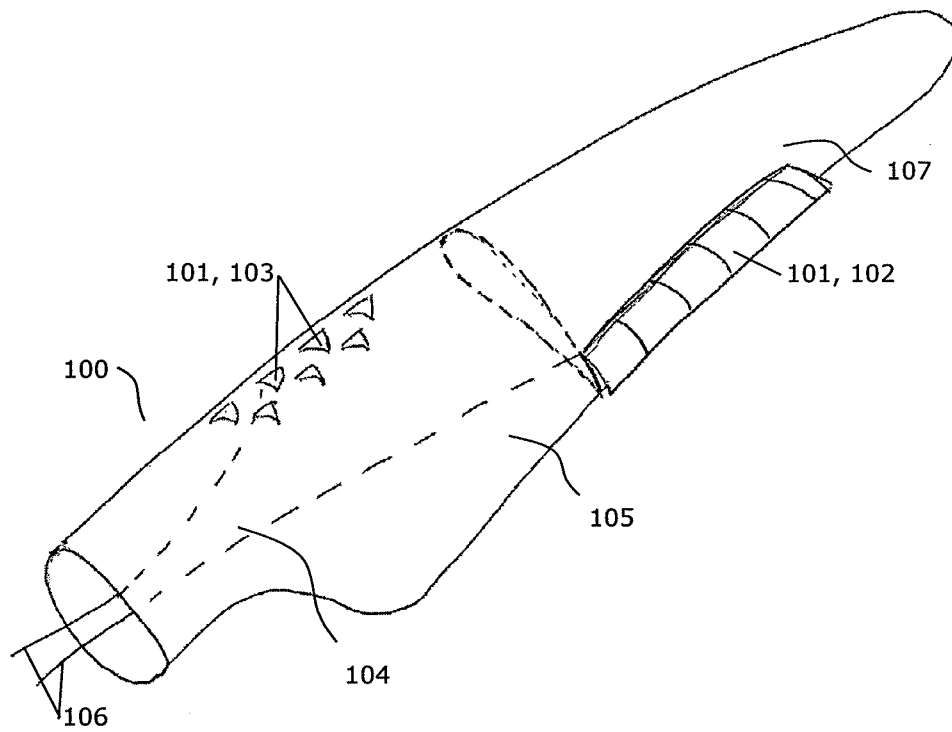


Fig. 1 (prior art)

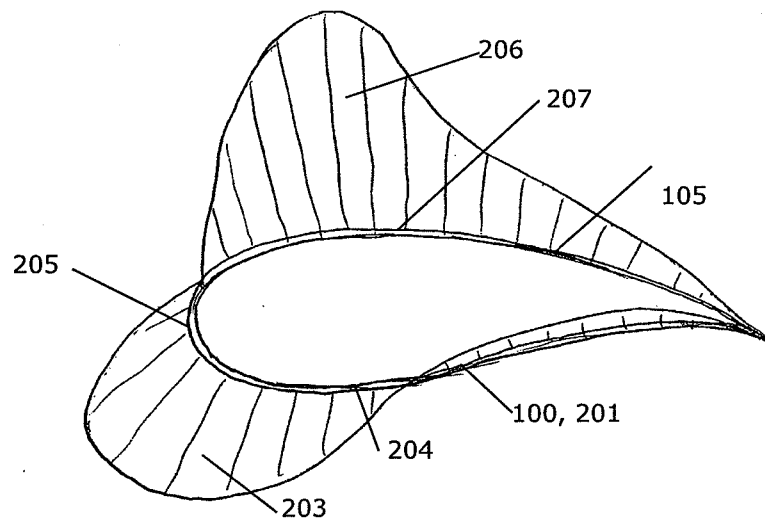


Fig. 2 (prior art)

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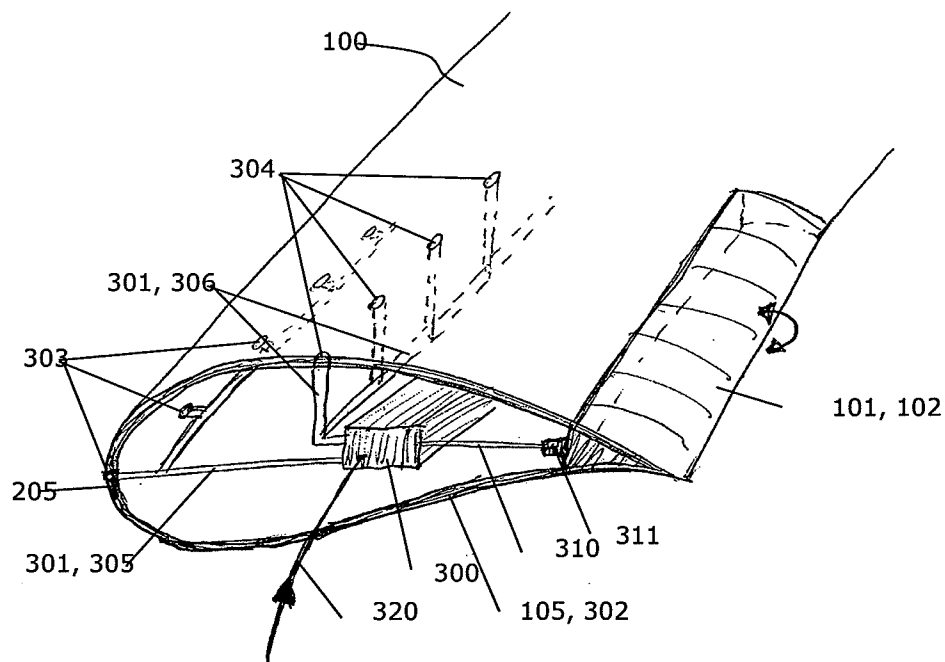


Fig. 3

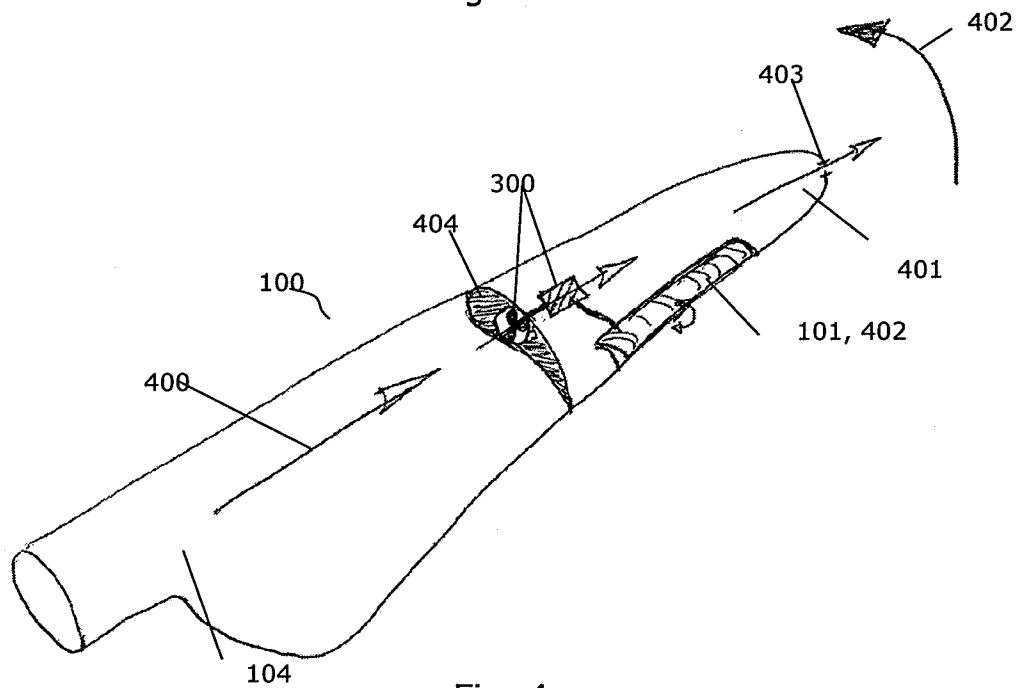


Fig. 4

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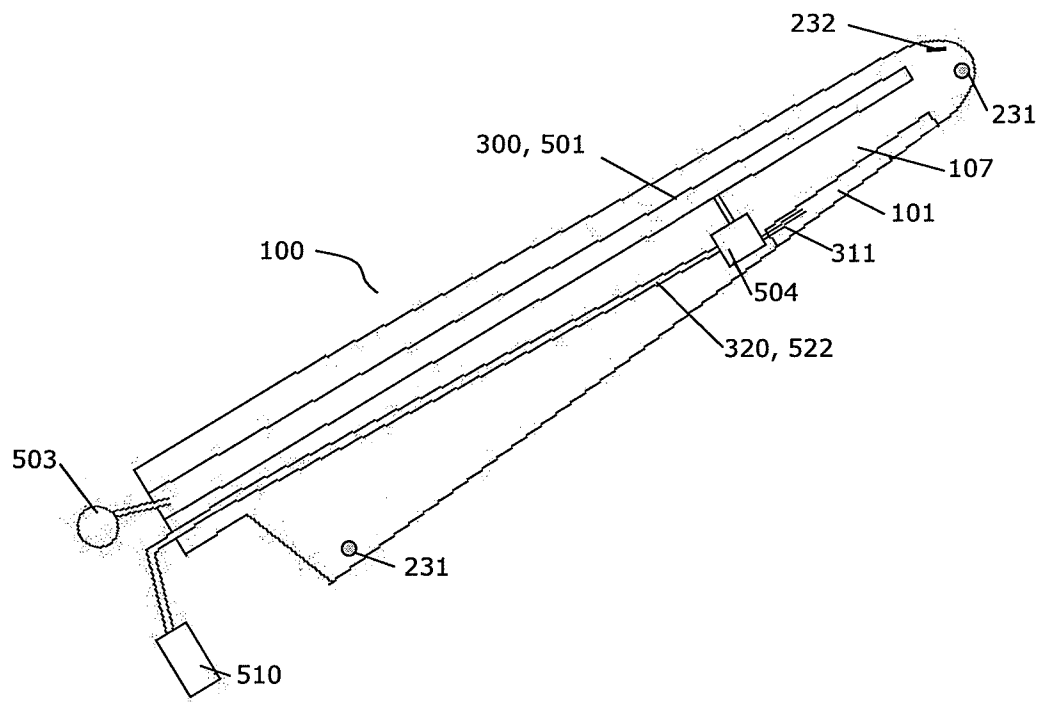


Fig. 5

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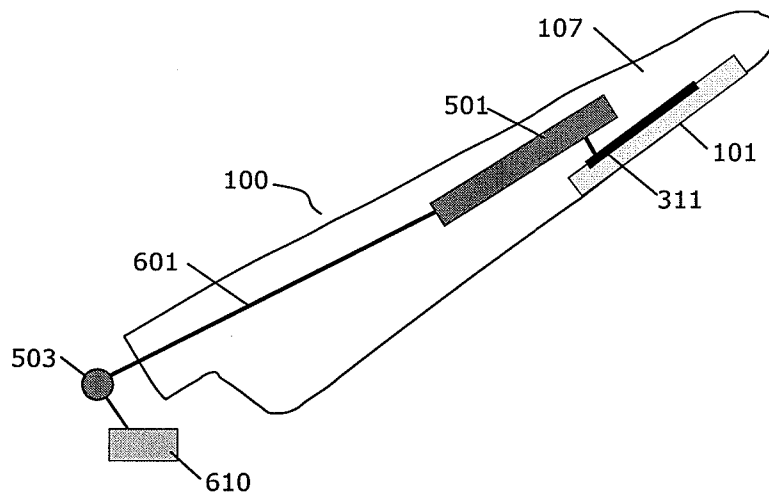


Fig. 6

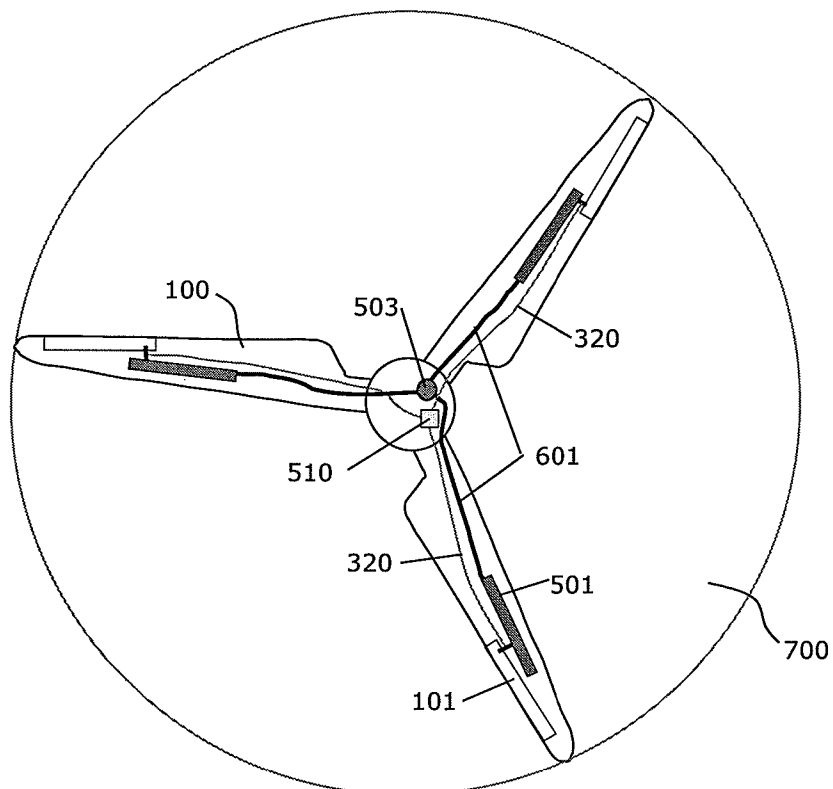


Fig. 7