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(54) Benævnelse: **Fremgangsmåde og indretning til styring af et tøjret flyveelement.**

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The invention relates to a method for controlling a tethered flying element, in particular a kite, which is connected to a retaining point by means of at least one tension rope. In particular, the invention relates to a pull-in procedure for such a flying element.

In this connection, a flying element is to be understood to mean an aerodynamically effective profile, which produces an aerodynamic force under the incidental wind flow. The flying element is tethered, by which it is to be understood to mean that the flying element is connected by means of at least one retaining element, in particular, a tension rope, to a retaining point. This retaining point can, for example, be arranged stationary on the ground or on a platform anchored to the body of water, for example, for cases of application, in which the flying element is used in a cyclical pull-in and veering out process for the generation of energy from wind power. The retaining point can also be arranged on a vessel, in order to generate and to transfer a tensile force as driving force for this vessel by means of the flying element. In particular, it is preferable, in this case to arrange the retaining point in the area of the bow, in order hereby to obtain favourable conditions for the introduction of the tensile force, the setting procedure and the retrieval procedure of the flying element.

Systems with flying elements of this type are already known. Thus, for example, a flying element is already known from EP 2 054 295 B1 and WO 2009/026939 A1, which serves the purpose of driving a vessel. Furthermore, a flying element is known from US 7,504,741 B2 which is considered to be the closest prior art, which serves the purpose of generating electrical energy from a regenerative wind power source. It is to be understood, that the thus already known flying element and the already known systems developed with this flying element made of tension rope and retaining point and in particular the control devices provided for this, such as, for example, a gondola arranged underneath the flying element, from which the tension rope extends to the retaining point on the ground side or vessel side, are suitable for the flying elements and flying systems according to this invention in particular and these can be designed accordingly. The disclosure of EP 2 054 295 B1 and of WO 2009/026939 A1 as well as US 7,504,741 B2 are referred to extensively concerning this matter.

It is known to keep the flying element in a stable position in a stationary or dynamic manner in a wind window by manual and in particular by automatic control procedures during the launching and landing of such flying elements. A wind window is defined in this connection of such a type, that starting from a retaining point and a wind of a specific direction and strength acting in relation to this retaining point it defines an area, in which the flying element occupies a stable flight attitude with the given tension rope length. As a result, the wind window comprises the spherical segment-shaped area lying leeward of a curve, wherein on the curve the flying element can be kept stationary and the radius of the spherical segment is defined by the tension rope length. A stable flight attitude is to be understood in this connection to mean that the flying element supports itself independently in this wind window, i.e. free from active drive influences is able to maintain its flying position.

Basically, with such an approach, even with changing wind conditions, for example, in the case of gusty wind conditions, and even in the event that the flying element must be launched or landed from a moving vessel, a launching and landing procedure must be carried out insofar as reliable. The veering out of the flying element and/or the pulling in of the flying element occurs here in the course of launching and landing by appropriate triggering of the flying element and balancing of any fluctuating influences due to the travel of the ship or changing wind conditions.

However, such a veering-out and pulling-in procedure makes use of a significant time period and in addition is very expensive in respect of the required control technology. This expense increases in particular when the flying element has a very large aerodynamically effective surface area, for example, a surface area of more than 150 m^2, in particular, surface areas in the range of between 300 and 1,200 m^2.

In order even in the case of such large-scale flying elements to be able to carry out a veering-out and pulling-in procedure reliably with respect to control technology and reasonably with respect to the required time period, it is known to make the fling element smaller in its aerodynamically effective surface area during the flight by reefing lines. A reefing is understood in this sense to be a reduction of the surface area of the flying element projected in the tension rope direction. Through this a launching or landing procedure can be implemented even with very large flying elements, if an appropriately reliable maintenance of an aerodynamically effective profile is ensured in the course of the reefing procedure. However, in the case of this embodiment or approach a significant design expense is required, in order to carry into execution the appropriate reduction of the aerodynamically effective surface area in a reliable manner such that in this connection the flying element is reduced uniformly with regard to its aerodynamic central longitudinal axis and in this connection maintains a reliably controllable aerodynamically effective profile.

A fundamental problem, which ensues in connection with such flying elements, constitutes the necessity of being able to pull in the flying element in certain operating situations in an as short a time as possible and under as low a load of the components of the entire flying element system as possible. Such a situation can occur, for example, if as a result of a rapid change in the weather a weather situation arises, in which a reliable operation of the flying element system is no longer guaranteed and the flying element must therefore be pulled in in a short time from possibly a great height. In the special case of the use of the flying element as the ship’s propulsion such a situation can occur, which makes a rapid pull-in procedure required, for example, in the course of sudden changes of course, manoeuvres, evasive movements of the vessel, for example, as a result of a risk of collision.

When using such flying elements in wind energy plants, which use the tensile force of the flying elements to generate energy through cyclical veering-out and pulling-in, for example, through conversion of tensile force and path into electrical energy, an endeavour also exists to increase the efficiency of these wind energy plants.

The problem addressed by the invention is to provide a control procedure or a control device, which is able to actuate a flying element to overcome the aforementioned problems in a better way than possible in the prior art.

This problem is achieved according to the invention by a method for controlling a tethered flying element, in particular a kite, which is connected to a retaining point by means of at least one tension rope, in which a pull-in procedure of the flying element is implemented with the steps:

- Controlling the kite at the edge of a wind window, inside of which the flying element assumes a stable flying position while a tensile force is applied to the tension rope when a wind having a specified wind direction and wind strength is incident on the flying element and outside of which the flying element cannot assume a stable flying position,

- pulling the at least one tension rope in,

- moving the flying element into a position outside of the wind window while the tension rope is being pulled in and

- pulling the flying element in along a flight path that lies at least partially outside of the wind window.

With the control procedure according to the present invention a specific control of a pull-in procedure is made possible, which is able to significantly reduce the forces, which act on the flying element and in particular on the tension rope during the pull-in procedure and at the same time to significantly increase the velocity, with which the flying element is pulled in. These advantageous effects are achieved, while the flying element is not pulled in, as in the prior art, in a stationary stable flight condition in the wind window, but rather is instead pulled in at least partially, preferably substantially or completely along a path, which lies outside of the wind window. According to the definition, the flying element is located on a point of this path outside of the wind window in a non-stationary stable flight condition, i.e., the flying element would pass into an unstable flight condition at this point and would be in danger of crashing or would crash. This undesirable unstable flight condition is overcome according to the invention in that the pull-in procedure itself is used as a dynamic influence on the flying element. It was recognised according to the invention that through the pull-in procedure on the flying element a relative wind velocity is generated in respect to the retaining point, which can be used advantageously for a dynamic stabilisation of the flight condition of the flying element outside of the wind window.

It is advantageously achieved through this approach, that the flying element can be manoeuvred into an area, in which the incidental wind flow on the flying element produces lower forces on the flying element and thus also on the flight rope than this would be the case in the wind window. The thus operating aerodynamic forces due to the apparent wind applied to the retaining point are thereby much smaller depending on how far the flying element is steered out of the wind window, i.e. at what distance the flying element is pulled in toward the wind window along the path, and thus make possible a very high pull-in velocity of the flying element through pulling the tension rope in, without the hereby permissible load limits on the load-bearing structures of the flying element system being exceeded. Basically the thus occurring pull-in procedure can be defined as a controlled crash outside of the stable wind window or be understood by a pull-in procedure windward of the stable wind window. At the same time, it can basically be assumed, that the more distant the pull-in path can be spaced apart from the wind window, the higher the pull-in velocity is selected, since with an increase in the pull-in velocity the stabilisation effect is also similarly increased by the relative wind thus achieved on the flying element.

According to a first preferred embodiment it is provided that the wind window occupies a section of a sphere spanned by the tension rope at a constant length, which is limited by a curved limit, on which the flying element can be held stably stationary, and that the flying element is moved beyond this limit of the wind window for implementing the pull-in procedure. According to this preferred embodiment a favourable course of the pull-in path is proposed in the case of a typical wind window cut, which is preferably formed as a tapered piece of pie, the tip of which is consistent with the retaining point. The limits of such a typical wind window lie thereby, for example, defined as the lower limit on an approximately horizontal plane pointed slightly upwards originating from the retaining point and as the upper limit on a surface area slightly inclined to the lower plane almost vertical from the retaining point. The wind window thus extends over a three-dimensional space, which originating from the retaining point is located leeward of the retaining point in regard to the apparent wind at the retaining point. This space is also laterally limited and could extend in a horizontal plane laterally at an angle of less than 90 degrees, depending on how good the aerodynamic properties of the flying element are high in the wind. According to the preferred embodiment, the flying element is now pulled in windward of this wind window, i.e., it runs on a pull-in path, which, for example, can be an approximately vertical path above the retaining point, wherein it must be understood, that the pull-in path can also be a bent curve and in particular also a path, which can run significantly windward to a plane lying vertical over the retaining point and transverse to the apparent wind direction at the retaining point.

According to a further preferred embodiment it is provided, that the flying element comprises an aerodynamic profile extending on both sides about a central longitudinal axis with a preferably at least partially, preferably completely loose shell, which is connected by means of several steering lines extending from both sides of the aerodynamic profile to a gondola arranged beneath the profile, which is connected by means of the tension rope with the retaining point, and the flying element is steered by alternately shortening and/or lengthening the steering lines on the individual sides, the flying element is pulled in by shortening the tension rope. Alternatively thereto the flying element can also be formed by a rigid profile or the flying element can be formed by a combination of rigid shell elements and loose shell elements.

According to this preferred embodiment an especially advantageous control mode is used in connection with a specific structure of a flying element, which is suitable for the control of large flying elements and at the same time makes it possible to be able to reduce these large flying elements in a favourable manner with regard to their volume and their dimensions, for example, to be able to stow these away after a pull-in procedure. At the same time, a partially loose shell is to be understood to mean that the flying element is formed, for example, from two top layers made of a loose material, for example, fabric, canvas or the like, which permits a folding, reefing, wherein this fabric reinforces through elements which are partially rigid, possibly flexible within limits and can be stabilised in its aerodynamic form. Such rigid, possibly flexible elements can, for example, be formed in the form of sail battens or bodies filled with air, however, possibly can also be arranged in the form of a rigid kite stick in the pivotal central longitudinal axis of the flying element, in order to create hereby pivot points for reefing lines, constructive space for actuators and the like. Through the arrangement of a gondola directly underneath the flying element it is made possible to connect such a flying element through a single tension rope with the retaining point and thus the weight forces to be borne due to this tension rope are minimised. The length of the tension rope thereby corresponds approximately to the flight altitude of the flying element and the numerous steering lines and tethers, which stabilise and change the flying element in its aerodynamic form for the purpose of steering, are merely spanned between the flying element and the gondola over a short distance. In the gondola, appropriate forces can in turn be introduced to the steering lines through provision of appropriate actuators, deflection rollers and the like, wherein the energy necessary for this purpose can be stored in the gondola or provided by means of transfer elements, for example, an electrical conduit cable running in the tension rope.

Still further, it is preferred, that the flying element comprises an aerodynamic profile with an at least partially, preferably completely loose shell, which during the pull-in procedure, preferably at the end of the pull-in procedure is reefed in such a manner that the effective wind-exposed surface of the flying element is reduced. According to this preferred embodiment, the pull-in procedure is facilitated in an additional manner and an acceleration of the pull-in procedure or its operation at a higher velocity is made possible, while the aerodynamically effective surface area of the flying element during the pull-in procedure is reduced in relation to the completely usable surface condition of the flying element. For example, this can be done by reef lines, which run in the flying element itself or outside of the flying element and which activated by an actuator are shortened to initiate a pull-in procedure. Through such a reefing of the flying element in particular the sensitivity to dynamic changes of the wind conditions according to direction and strength can be reduced and thus the stability of the flight condition is also increased during the pulling in according to the present invention on a path outside of the wind window.

According to a further preferred embodiment it is provided that the flying element is pulled in with a winch velocity of the tension rope and is steered into a position outside of the wind window, at which the vector sum from the winch velocity vector, represented by the velocity, with which the tension rope is pulled in and the direction in which the tension rope engages the gondola and the apparent winch velocity vector prevailing with regard to the retaining point in the area of the wind element, represented by the vector sum from the velocity and direction of the true wind and a possibly existing travel velocity and travel direction of the retaining point causes an effective incident flow of the flying element outside of the wind window, which is less than the effective incident flow of the flying element in the wind window as a result of the apparent wind in the wind window prevailing in relation to the retaining point.

According to this preferred embodiment an effective incident flow of the flying element is to be understood to mean those components of wind according to strength and direction, which bring about an aerodynamic force on the flying element. Depending on the wind direction and strength these effective incident flow components can change depending on the angle of attack of the flying element to the apparent wind. Furthermore, the pull-in procedure has an impact on this effective incident flow, since due to the relative movement of the flying element caused thereby in regard to the retaining point, therefore, in particular, the approach of the flying element, an incident flow of the flying element in the form of a pull-in-path wind adds to the apparent wind. According to the preferred embodiment, the effect of the wind added from all of these impacts in the form of the corresponding vector addition of the wind impacts during the pull-in procedure is less than during an operation of the flying element in the wind window, in particular, during an operation of the flying element in the wind window during implementation of a pull-in procedure with corresponding pull-in velocity. Through the selection of the pull-in path and the pull-in velocity in the case of increased pull-in velocity it is achieved that the forces acting here on the flying element and all of the components of the flying element system are reduced, whereby an increase of the pull-in velocity is made possible during the simultaneous reduction of the forces acting on the flying element system.

According to yet another preferred embodiment it is provided, that the flying element is pulled in with a winch velocity of the tension rope, which corresponds to 0.5 to 1.2 times the velocity of the apparent wind in regard to the retaining point. According the present invention, it is shown, that with 0.5 to 1.2 times the velocity of the pulling in in regard to the wind velocity of the apparent wind a preferred path outside of the wind window can be used for the pull-in procedure, which in a stably dynamic flight attitude of the flying element produces an especially quick pull-in procedure with low forces on the flying element system.

Finally, the method according to the present invention can be further developed, while the flying element is pulled in on a flight path, which essentially has no movement components in a direction perpendicular to the tension rope. With this form of further development, the tensile force can be reduced again, while aerodynamic lifting forces, which occur through a movement and corresponding airstream occurring tangential to the tension rope, are prevented.

A further aspect of the invention is a control device for a tethered flying element, in particular a kite, which is connected by means of a tension rope to a retaining point, comprising:

- a winch with a winch drive, by means of which the tension rope can be pulled in,

- an actuator for the shortening and lengthening of steering lines, which are fastened on the flying element in such a manner that a shortening or lengthening of the steering lines causes a steering movement of the kite under an incident wind flow,

- an electronic control unit, which is coupled by means of signals with the winch drive and the actuator and is designed, in order to trigger the actuator, that the actuator is triggered so that the flying element flies outside of a wind window, inside of which the flying element assumes a stable, static flying position while a tensile force is applied to the tension rope when a wind having a specified wind direction and strength is incident on the flying element and outside of which the flying element cannot assume a stable, static flying position and here at the same time

- to trigger the winch drive so that the tension rope is pulled in with such a winch velocity, that the flying element assumes a stable flying position.

The thus designed control device is suitable in particular to carrying out a control procedure and a pull-in procedure of the previously described type. Reference is made in regard to the features and advantages as well as design variants of the components provided on the control device for this to the above explanations, advantages and variants regarding the control procedure according to the present invention.

The control procedure can be further developed, while the wind window occupies a section of a sphere spanned by the tension rope at a constant length, which is limited by an upper and lower limit and the control unit is designed in order to trigger the actuator so that the flying element is steered beyond the upper limit of the wind window towards the outside of the wind window for implementing the pull-in procedure.

Furthermore, the control device can be further developed, while the flying element comprises an aerodynamic profile with an at least partially, preferably completely loose shell and that the flying element comprises a second actuator, by means of which a reefing of the flying element can be effected and that the control unit is coupled by means of signals with the second actuator and is designed in order to trigger the second actuator so that the flying element is reefed during the pull-in procedure, preferably at the end of the pull-in procedure in such a manner, that the effective wind-exposed surface of the flying element is reduced.

Furthermore, the control device can be further developed, while the control unit is designed in order to trigger the winch drive and the actuator so that the flying element is pulled in with such a winch velocity of the tension rope and is steered into a position outside of the wind window, at which the vector sum from the winch velocity vector, represented by the velocity, with which the tension rope is pulled in and the direction, in which the tension rope engages the gondola, and the apparent winch velocity vector prevailing with regard to the retaining point in the area of the wind element, represented by the vector sum from the velocity and direction of the true wind and a possibly existing travel velocity and travelling direction of the retaining point, causes an effective incident flow of the flying element outside of the wind window, which is less than the effective incident flow of the flying element in the wind window as a result of the apparent wind in the wind window prevailing in regard to the retaining point.

Furthermore, the control unit can be further developed, while the control unit is designed, in order to trigger the winch drive and the actuator so that the flying element is pulled in with a winch velocity of the tension rope, which corresponds to 0.5 to 1.2 times the velocity of the apparent wind in regard to the retaining point.

In regard to these further developments of the control device, reference is also made to the above explanations of the control procedure corresponding to this.

A further aspect of the invention is a computer program product, which is designed in order to implement a control procedure of the previously described kind, if it runs on a computer.

A further aspect of the invention is a wind energy plant, with a flying element, which is tethered by means of a tension rope at a retaining point, a tension rope, which connects the flying element to a winch, a winch drive for driving the winch, at least one, preferably two or more steering lines, which are fastened to the flying element in such a manner that an optional shortening and/or lengthening of the steering line(s) causes a change in the flight direction of the flying element, an actuator for the optional shortening/lengthening of the steering line(s), characterised by a control device according to the previously described design. Such a wind energy plant can serve to generate energy from wind power, for example, electrical energy, or can be used to transfer a driving energy in the form of a tensile force to a vehicle, in particular to a vessel. The wind energy plant thereby benefits significantly from the pull-in procedure according to the present invention, while the energy and the pull-in time, which must be expended for this pull-in procedure, can be significantly reduced and the efficiency of the wind energy plant can be effectively increased in this way. The work can thereby be calculated from the integral of the pull-in tensile force over the pull-in path and thus according to the present invention opens up the way to increase the efficiency of the wind energy plant through a rapid pulling in by accepting an appreciable tension rope force or through a slow pulling in with substantially reduced tension rope force.

A further aspect of the invention is the use of a control device of the previously described design for pulling in a flying element serving as ship propulsion.

Preferred embodiments are explained by means of the attached figures:

Fig. 1 shows a schematic side view of a flying element according to the invention in the use as a drive for a vessel in normal drive mode,

Fig. 2 shows a top view of the arrangement according to Fig. 1,

Fig. 3 shows a view according to Fig. 1 in one phase of the initiation of a pull-in procedure of the flying element,

Fig. 4 shows a view according to Fig. 1 in one phase of the pull-in procedure,

Fig. 5 shows a view according to Fig. 1 in one phase of the pull-in procedure of the flying element,

Fig. 6 shows a vector graphic with representation of the connections of the winch velocity, the wind velocity and the aerodynamically effective wind velocity on the flying element, and

Fig. 7 shows a schematic representation of a flight path of a flying element according in the present invention in the use in a wind energy plant.

In reference initially to Figs. 1 and 2 a vessel 10 is shown, on which a winch 20 is mounted in a bow area 11. On the winch 20 a tension rope 21 is reeled up, which is partially veered out and connects a vessel 10 with a flying element 30 via a deflection device 22.

The winch 20 and the deflection point 22 constitute in this connection the retaining point of the tension rope on the vessel 10. The tension rope 21 connects the ship with a gondola 31, which is a component of the flying element 30 and is located at the same height as an aerodynamic profile 33 connected with this gondola via several pulling and steering lines 32. The aerodynamic profile 33 is designed as a double top layer made of canvas and has a central kite stick 34.

In Figs. 1 and 2 a course and wind situation is depicted, in which a true wind 1 comes in from starboard aft. This true wind 1 is added together with an airstream 2 of the vessel 10 to an apparent wind 3, which acts in relation to the retaining point on the flying element 30. This apparent wind 3 can in turn be broken up into a wind component $V_{effective}$ effective for the aerodynamic lifting forces acting tangential to the tension rope and a component acting perpendicular hereto in the direction of the tension rope and determines the tensile forces applied to the tension rope 21 by the flying element 30. In all areas of the wind window with the exception of its edge a flight velocity arising as a result of the flight movements of the flying element 30 at constant tension rope length is added to this consideration of the effective wind component from the apparent wind, which flight velocity achieves a substantial increase of the effective wind engaging the flying element. A substantial increase in the tension rope force results from this.

From the direction of the true wind, the strength of the true wind and the travel direction and travel velocity of the vessel a wind window 40 results, inside of which the flying element 30 can be kept stably in a stationary flight condition. This wind window 40 is determined by an angle α in a perpendicular plane and an angle β in a horizontal plane. The angles α and β are in conformity in practical systems. These angles starting from the deflection point 22 on the vessel 10 define approximately a half cone, the tip of which constitutes the retaining point and the flat lower limit of which is defined as the case may be in practical systems by the horizon. Inside of this half cone the flying element can fly stably and on the upper, curved edge, which the flying element approaches from the wind window with a velocity asymptotically decreasing to zero, the flying element can be kept stationary.

As is clear from Fig. 3, the flying element for initiating a pull-in procedure is initially brought to a maximum height on the windward-side edge 41 of this wind window. Already this manoeuvring movement of the flying element within the wind window can be supported by a pull-in procedure by rotating the winch, however, this is not urgently required for the reliable operation of the pull-in procedure, since the flying element can still fly stably stationary in the wind window until reaching the windward-side limit 41.

The winch procedure already begun by activation of the winch 20 and pulling in the tension rope 21 during the manoeuvre in the wind window or the winch procedure begun when reaching or exceeding the windward-side limit 41 of the wind window now generates on the flying element 30 an additional relative movement in relation to the air, which enters into the consideration of the wind forces engaging the flying element. Through this additional wind influence quantity, it becomes possible to move the flying element dynamically outside of the wind window 40 and to pull it in on a dynamic pull-in path 50 windward of this wind window. The dynamic of the pull-in path results thereby from the pull-in procedure of the tension rope. It can be superimposed by flight movements tangential to the tension rope, however, this is not required for the pull-in procedure according to the present invention and is also as a rule not advantageous due to the increase in the tension rope force associated therewith. The pull-in path 50 can thereby, as is clear from Fig. 4, run on a bent curve and possibly have a considerable distance from the windward-side limit 41 of the wind window 40. It is to be understood that the course of the pull-in path 50 depends on several factors, including the travel velocity of the ship and the pull-in velocity of the tension rope, i.e. the winch velocity.

Fig. 5 illustrates the wind conditions on the flying element during the pull-in procedure. As is clear, an effective incident wind flow is delivered to the flying element, which consists of the components of the apparent wind and the winch direction, which flows into the flying element 30 in an aerodynamically effective manner. This effectively active inflowing wind component produces a tensile force on the rope and in the endeavour to pull in the flying element 30 in the shortest possible time and with the least possible tensile force on the rope, the overall energy needed for the pull-in procedure can be significantly reduced.

Fig. 6 shows in the form of a vector graphic with a total of eight different pull-in control procedures, how according to the present invention the pull-in velocity increases or the forces acting during the pull-in procedure can be reduced. As can be seen, in the case of the system examined, for example, here, at a ratio of the winch velocity to the wind velocity of 0.3, 0.4 and 0.5 still no actual advantage results in terms of the effective wind to the wind ratio. However, starting from a ratio of the winch velocity to the wind velocity of 0.6 and higher the effective inflowing wind can be significantly reduced in proportion to the wind velocity and it is achieved, if the winch velocity corresponds to the wind velocity, for example, a halving of the effectively active wind to the wind velocity is achieved, therefore a reduction of the uplift by 75%.

In this connection, Fig. 7 shows a movement path of a flying element, which is used for a wind energy plant. Starting from a winch 120 coupled to an electrical generator 125 the flying element 130 is initially veered out along a veering out path 170 in a wind window spanned by the angle α leeward from the winch 120 in relation to the wind 101. Along this veering-out path the flying element performs work on the winch, which through mechanical coupling of the winch to the generator 125 is converted into electrical energy in the latter. To increase the efficiency the aim is to implement this veering out movement with as high a tension rope force as possible over as long a time period as possible. For this purpose, the flying element is moved on the veering out path perpendicular to the tension rope, for example, – as depicted – in the form of eights or in the form of circles, which lie in a plane perpendicular to the tension rope.

As soon as the tension rope is maximally veered out, a pull-in procedure is started. This pull-in procedure is depicted in Fig. 7 along a transfer path 180, along which the flying element moves within the wind window about a point above the winch 120 on the edge of the wind window. Starting from this edge the flying element then moves dynamically by actively winching into a position windward of the winch. However, it is to be understood that such a position windward of the winch can also be reached by a movement of the flying element on a horizontal flight path, which means without altitude gain of the flying element, for example on a flight path, which leads the flying element at a constant altitude to the edge of the wind window.

Already during the transfer path 180 the tension rope can be pulled in with low wind velocity. Upon reaching the limit of the wind window and leaving the wind window the winch velocity is increased and is also required to stabilise the flight stability of the flying element. Outside of the wind window the flying element is pulled in along a pull-in path 190 up to a lower tension rope length and in this connection is stabilised by a high winch velocity in its flight attitude. After reaching the lower tension rope length a veering out procedure is restarted along the veering out path 170 and the cycle for energy generation begins again.

P A T E N T K R A V

1. Fremgangsmåde til styring af et tøjret flyveelement (30), især en drage, der ved hjælp af mindst én trækline (21) er forbundet med et holdepunkt (20, 22), ved hvilket et indhentningsforløb af flyveelementet udføres med trinnene:

- styre dragen til kanten (41) af et vindvindue (40), inden for hvilket flyveelementet ved en vindtilstrømning i en forudbestemt vindretning og vindstyrke indtager en stabil flyveposition ved at anvende en trækkraft på trækline og uden for hvilket flyveelementet ikke kan indtage en stabil flyveposition,
- indhentning af den mindst ene trækline,
- under indhentning af træklinen bevægelse af flyveelementet til en position uden for vindvinduet og
- indhentning af flyveelementet langs en bane (50), som i det mindste delvist ligger uden for vindvinduet (40).

2. Fremgangsmåde ifølge krav 1,
k e n d e t e g n e t ved, at vindvinduet indtager en del af en udspændt sfære defineret ved træklinen (21) i konstant længde, hvilken sfære er afgrænset af en buet grænse, hvor flyveelement kan holdes stationært stabilt, og at flyveelementet ved udførelsen af indhentningsforløbet bevæger sig ud over denne grænse af vindvinduet.

3. Fremgangsmåde ifølge krav 1 eller 2,
k e n d e t e g n e t ved, at flyveelementet på begge sider omkring en central langsgående akse, der strækker sig langs en aerodynamisk profil (33), som omfatter et fortrinsvis i det mindste delvist, fortrinsvis fuldstændigt, slapt hylster, og som er forbundet til en gondol (31), som er anbragt under profilen, ved hjælp af flere styreliner (32), der strækker sig på begge sider af den aerodynamiske profil, og som er forbundet med holdepunktet ved hjælp af træklinen (21), og

- ved hjælp af skiftevis sideindividuel afkortning og/eller forlængelse af styrelinerne styres flyveelementet,
- ved hjælp af afkortning af træklinen indhentes flyveelementet.

4. Fremgangsmåde ifølge krav 1,
k e n d e t e g n e t ved, at flyveelementet omfatter en aerodynamisk profil med et i det mindste delvist, fortrinsvis fuldstændigt, slapt hylster, som under indhentningsforløbet, fortrinsvis i slutningen af indhentningsforløbet, rebes på en sådan måde, at den effektive vindangrebsflade af flyveelementet reduceres.

5. Fremgangsmåde ifølge et hvilket som helst af de foregående krav,
k e n d e t e g n e t ved, at flyveelementet indhentes ved en spilhastighed af træklinen og styres til en position uden for vindvinduet, hvor vektorsummen af

- spilhastighedsvektoren repræsenteret ved den hastighed, som træklinen hentes ind med, og den retning, i hvilken træklinen griber fat i gondolen, og

- den tilsyneladende fremherskende vindhastighedsvektor i forhold til holdepunktet i området af vindelementet, repræsenteret ved vektorsummen af hastigheden og retningen af den rigtige vind og en eventuelt eksisterende hastighed og retning af holdepunktet, forårsager en effektiv tilstrømning af flyveelementet uden for vinduet, der er mindre end den effektive tilstrømning af flyveelementet i vindvinduet i forhold til den tilsyneladende fremherskende vind i vindvinduet i forhold til holdepunktet.

6. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, kendetegnet ved, at flyveelementet indhentes ved en spilhastighed af trækklinen, der svarer til 0,5 til 1,2 gange hastigheden af den tilsyneladende vind i forhold til holdepunktet.

7. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, kendetegnet ved, at flyveelementet indhentes via en flyvebane, der i det væsentlige ingen bevægelsesandele omfatter i en retning vinkelret på trækklinen.

8. Styreindretning til et tøjret flyveelement (30), især en drage, der er forbundet ved hjælp af mindst én trækline (21) med et holdepunkt (20, 22), omfattende:
- et spil (20) med en spildrivanordning ved hjælp af hvilken trækklinen kan indhentes,
- en aktuator til afkortning og forlængelse af styreliner, hvilke er fastgjort til flyveelementet på en sådan måde, at en afkortning eller forlængelse af styrelinerne bevirker en styrebevægelse af dragen,
- en elektronisk styreenhed, som signalteknisk er koblet til spildrivanordningen og aktuatoren, og er udformet til at styre aktuatoren, kendetegnet ved, at aktuatoren bliver styret således, at flyveelementet flyver, udenfor et vindvindue, inden for hvilket flyveelementet ved en vindtilstrømning med en given vindretning og vindstyrke indtager en stabil, statisk flyveposition under påføring af en trækkraft på trækklinen, og uden for hvilket flyveelementet ikke kan indtage en stabil, statisk flyveposition, og herved samtidig
- styrer spildrivanordningen, så trækklinen indhentes med en sådan spilhastighed at flyveelementet indtager en stabil flyveposition.

9. Styreindretning ifølge krav 8, kendetegnet ved, at vindvinduet (40) indtager en del af en udspændt sfære som er defineret af trækklinen i en konstant længde, og som er afgrænset af en øvre og nedre grænse, og at styreenheden er indrettet til at styre aktuatoren på en sådan måde, at flyveelementet til udførelsen af et indhentningsforløb styres over den øvre grænse af vindvinduet i en retning uden for vindvinduet.

10. Styreindretning ifølge krav 8 eller 9, kendetegnet ved, at flyveelementet omfatter en aerodynamisk profil med et i det mindste delvist, fortrinsvis fuldstændigt, slapt hylster,
og at styreindretningen omfatter en anden aktuator, ved hjælp af hvilken en rebning af flyveelementet kan udføres,

og at styreenheden signalteknisk er koblet til den anden aktuator og er udformet til at styre den anden aktuator på en sådan måde, at flyveelementet under indhentningsforløbet, fortrinsvis i slutningen af indhentningsforløbet, bliver rebet på en sådan måde, at den effektive vindangrebsflade af flyveelementet reduceres.

11. Styreindretning ifølge et af de foregående krav 8-10, k e n d e t e g n e t ved, at styreenheden er indrettet til at styre spildrivanordningen og aktuatoren, på en sådan måde at flyveelementet indhentes med en sådan spilhastighed af træklinen og styres til en position uden for vinduet, hvor vektorsummen af

- spilhastighedsvektoren repræsenteret ved den hastighed, som træklinen indhentes med, og den retning, i hvilken træklinen griber fat i gondolen, og
- den tilsyneladende fremherskende vindhastighedsvektor i forhold til holdepunktet i området af vindelementet, repræsenteret ved vektorsummen af hastigheden og retningen af den rigtige vind og en eventuelt eksisterende hastighed og retning af holdepunktet,

forårsager en effektiv tilstrømning af flyveelementet uden for vindvinduet, der er mindre end den effektive tilstrømning af flyveelementet i vindvinduet i forhold til den tilsyneladende fremherskende vind i vindvinduet i forhold til holdepunktet.

12. Styreindretning ifølge et hvilket som helst af de foregående krav 8-11, k e n d e t e g n e t ved, at styreenheden er indrettet til at drive spildrivanordningen og aktuatoren, således at flyveelementet indhentes ved en spilhastighed af træklinen, der svarer til 0,5 til 1,2 gange hastigheden af den tilsyneladende vind i forhold til holdepunktet.

13. Computerprogramprodukt, som er konstrueret til at udføre en fremgangsmåde ifølge et hvilket som helst af de foregående krav 1 - 7, når det køres på en computer.

14. Vindenergianlæg, med

- et flyveelement, der er tøjret til et holdepunkt ved hjælp af en trækline,
- en trækline, der forbinder flyveelementet med et spil,
- en spildrivanordning til at drive spillet,
- mindst én, fortrinsvis to eller flere, styreliner, som er fastgjort til flyveelementet på en sådan måde, at en skiftevis afkortning og/eller forlængelse af styrelinen/styrelinerne forårsager en ændring i flyveretningen af flyveelementet,
- en aktuator til skiftevis afkortning og/eller forlængelse af styrelinen/styrelinerne

k e n d e t e g n e t ved, en styreindretning ifølge et hvilket som helst af de foregående krav 8-12.

15. Anvendelse af en styreindretning ifølge krav 8-12 til at indhente et flyveelement der tjener som skibsdriftsmiddel.

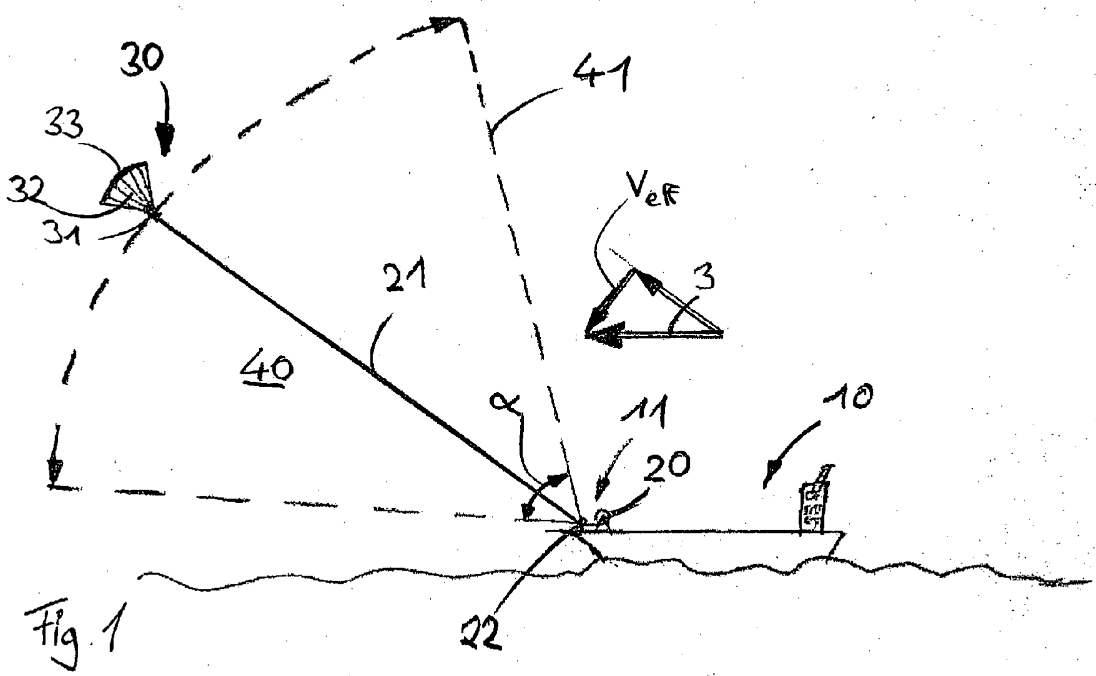


Fig. 1

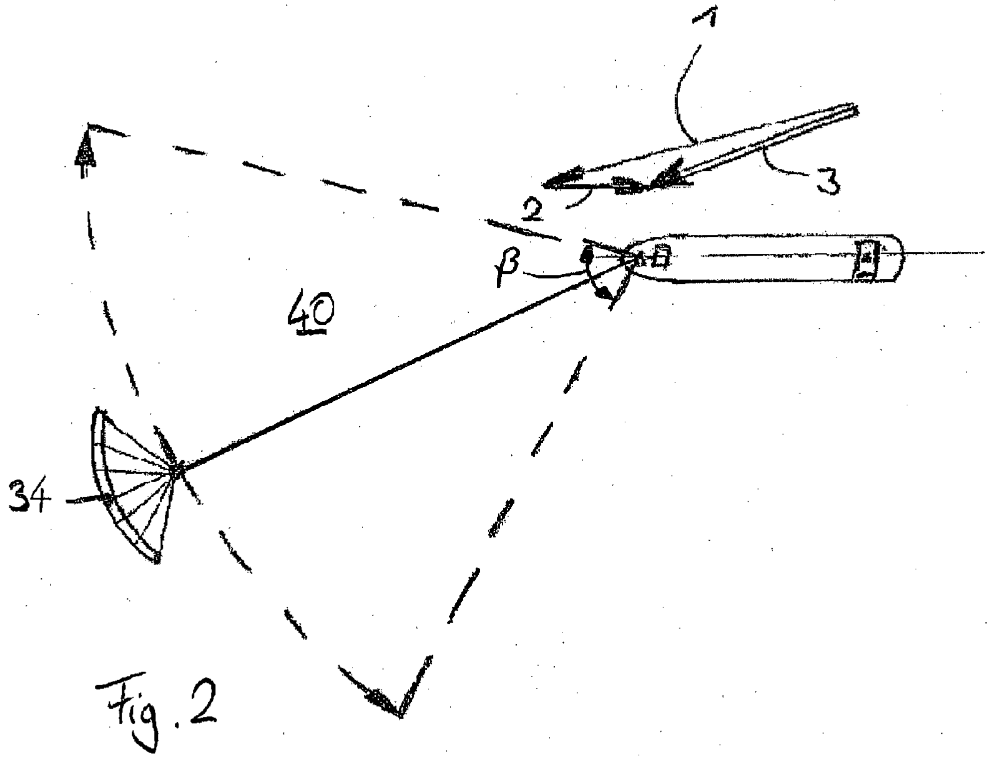


Fig. 2

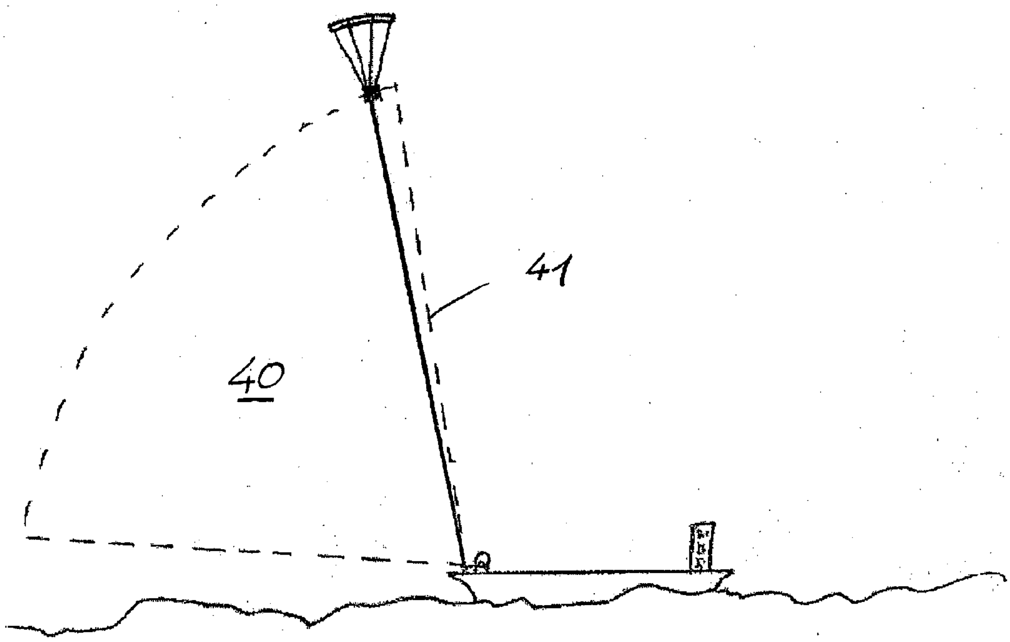


Fig. 3

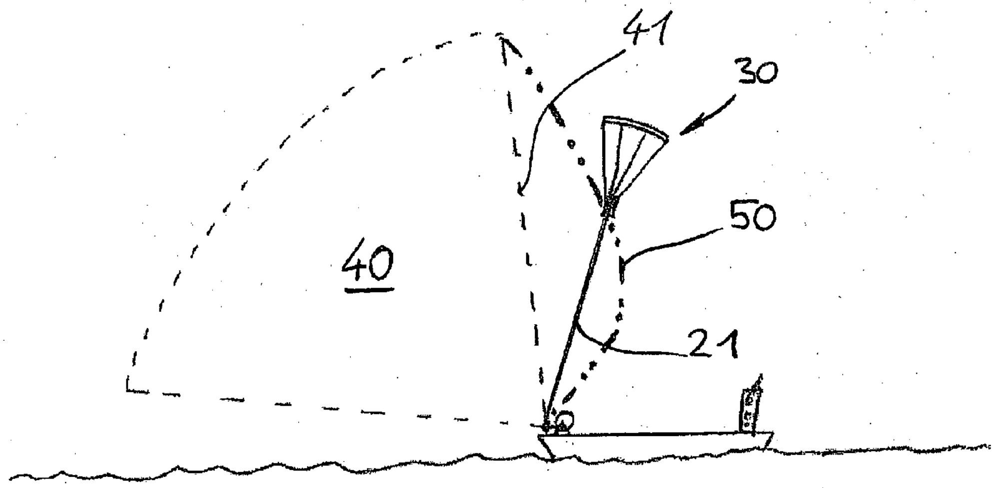


Fig. 4

Fig. 5

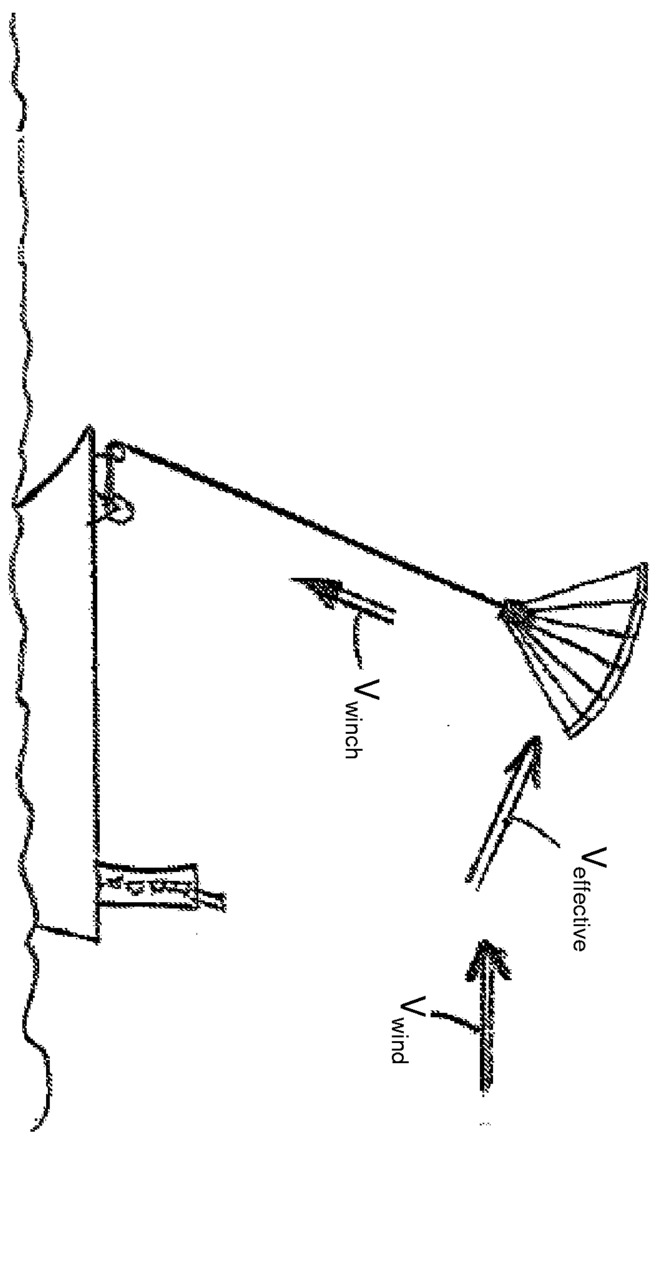
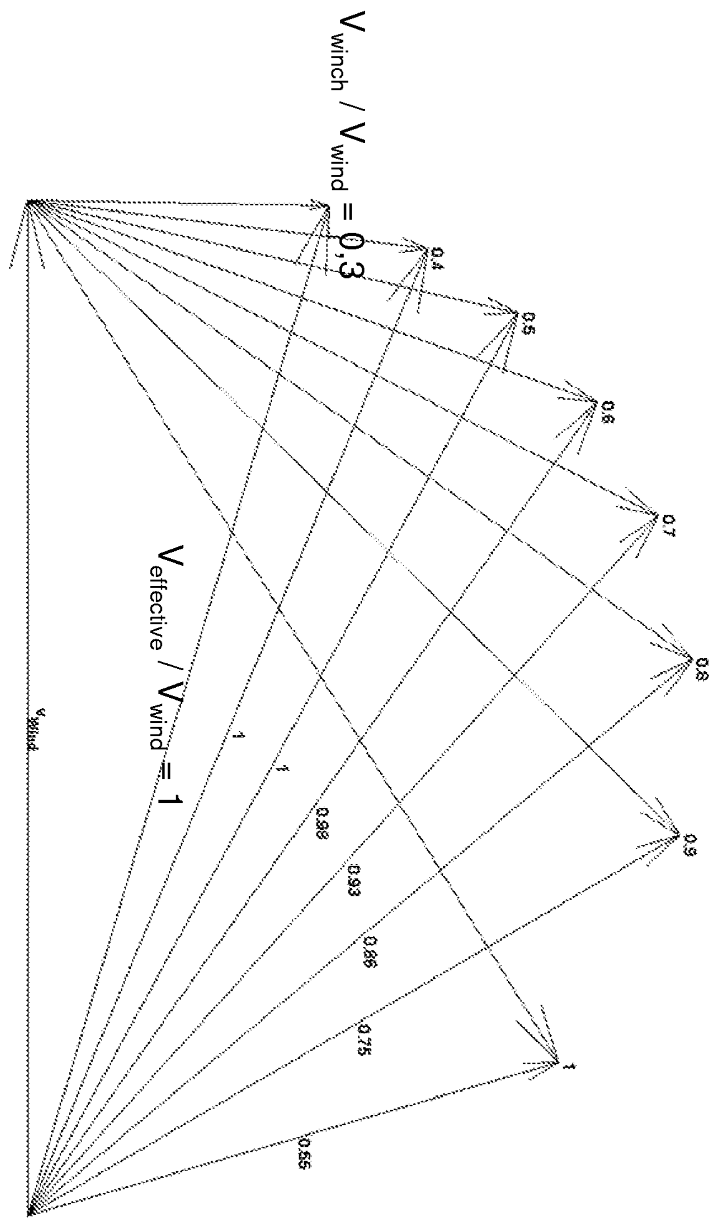


Fig. 6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V_effective / V_wind = 1
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0.5
0.6
0.7
0.8
0.9
1
0.98
0.93
0.86
0.75
0.55

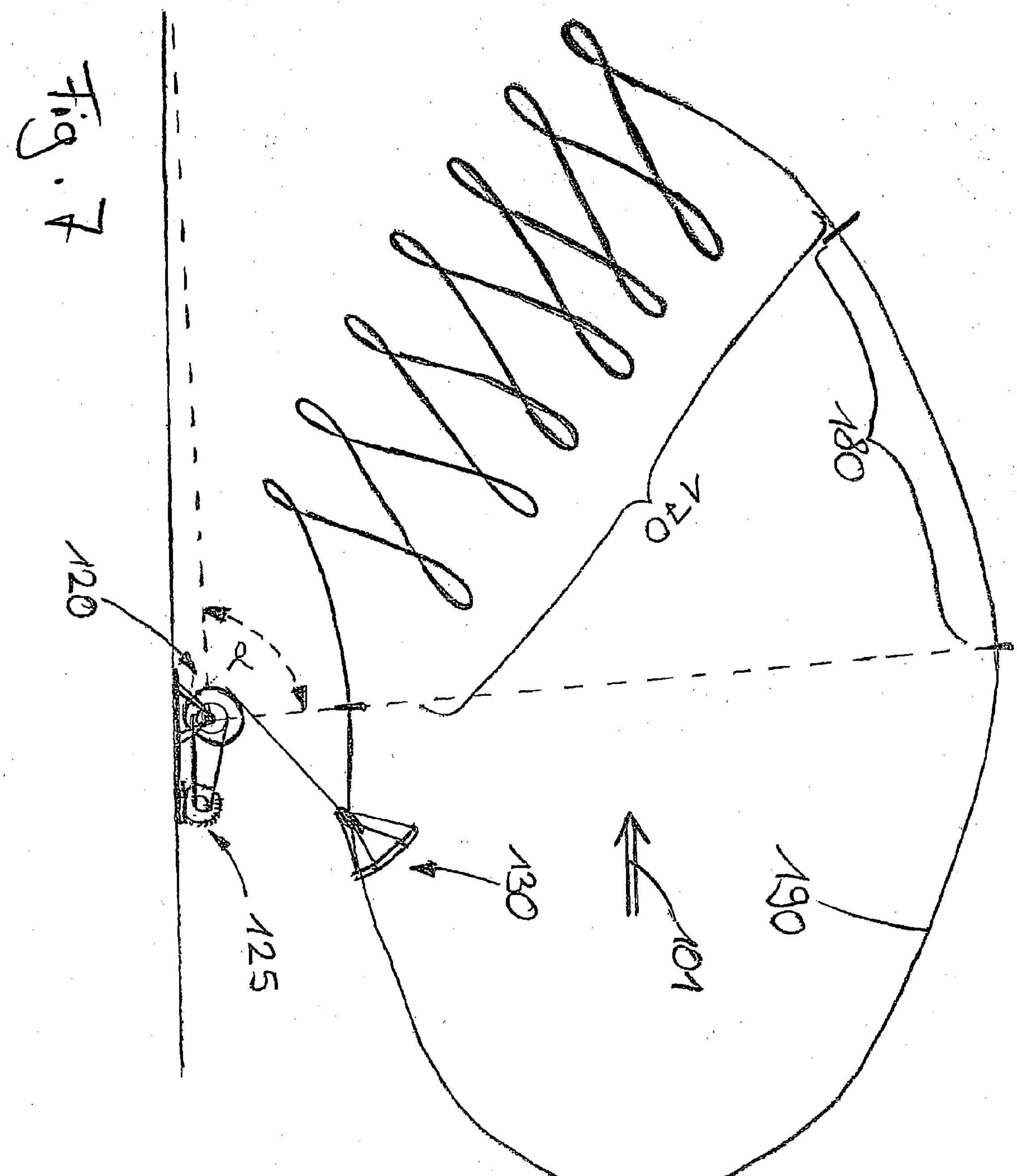

Fig. 7